

New Scientist

December 22, 2018 – January 4, 2019



2019 PREVIEW
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AI beats everything
Gene-screened babies
Bread back in fashion
Electric cars go big
Race to renewables
Artificial blood

HOLIDAY SPECIAL

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The strangest snow
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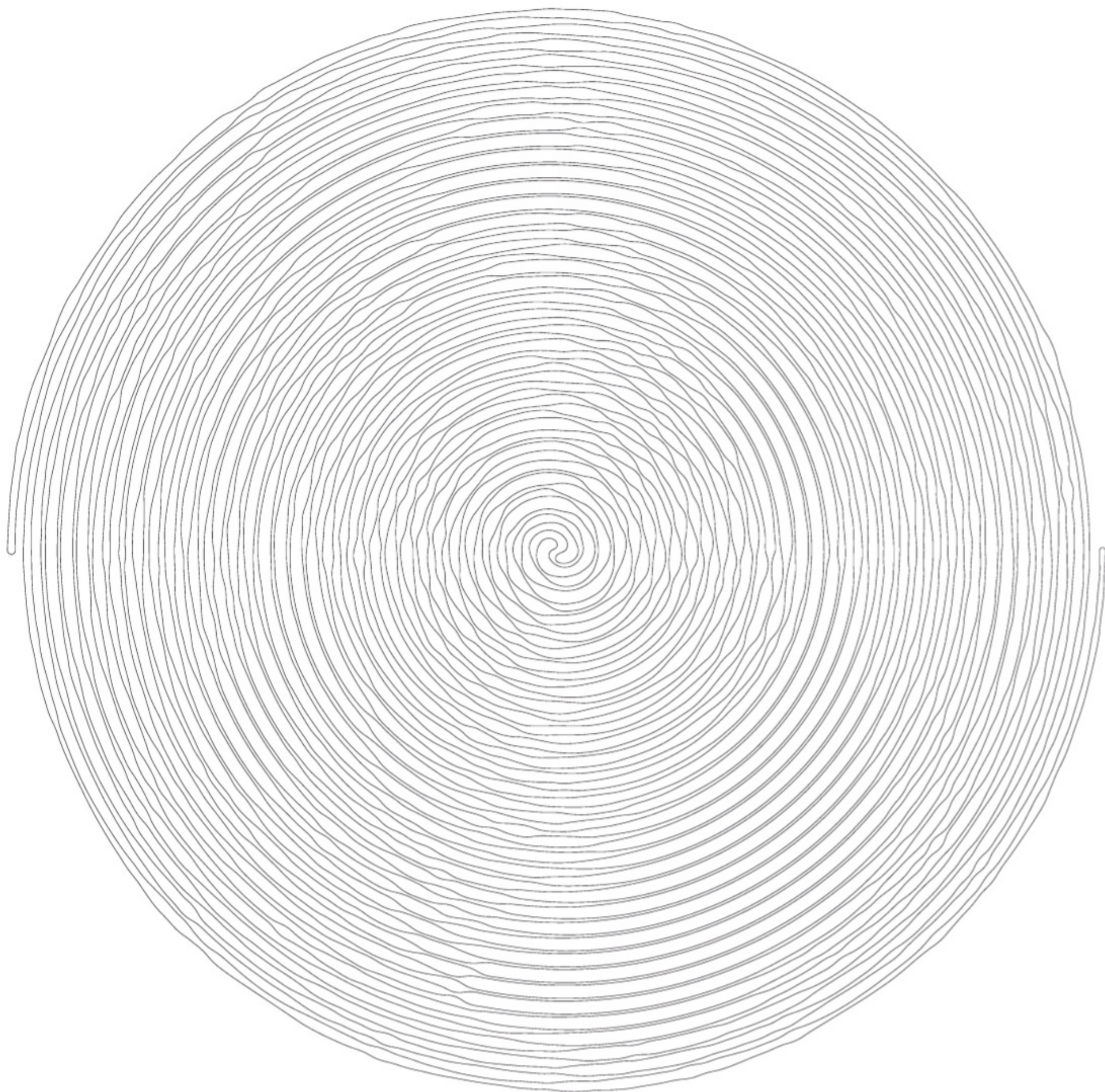


If you have completed the querkle challenge on the previous pages, shoot for the moon – it's just a small step to land on what this image is showing

HOW TO COLOUR A SPIROGLYPHIC

A spiroglyphic consists of two spirals, joined at the middle, that vary in width as they wind towards the centre. The simplest way to fill one in is to start at an outer end of the spiral (it doesn't matter which) and just colour towards the middle. Pause there to see if you

can discern what the image is, then work out along the other spiral to the edge again, hopefully to reveal it in its full glory. For different effects, colour the two spirals with different shades, or divide the spiroglyphic into sections, colouring each differently.

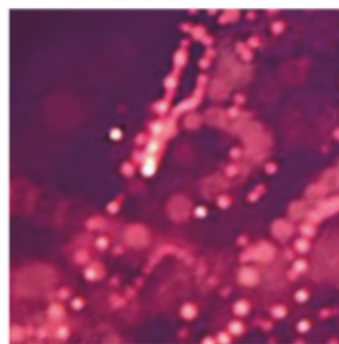
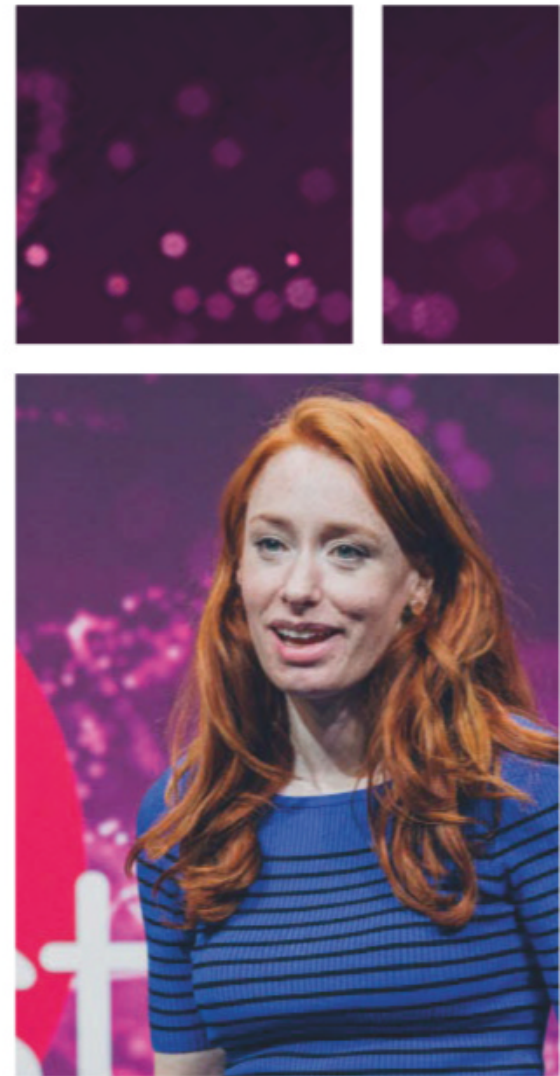


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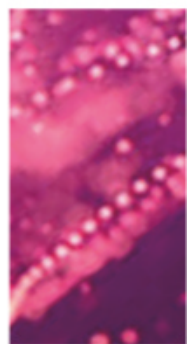
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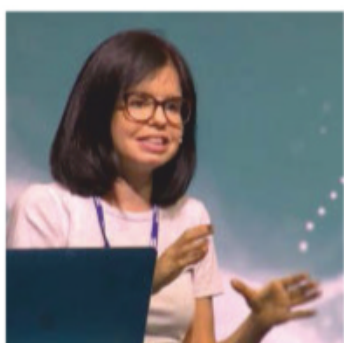
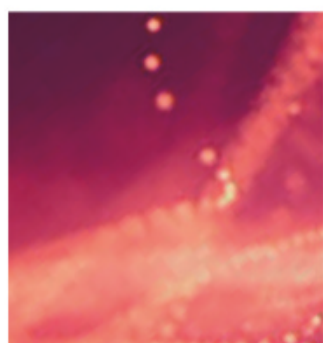
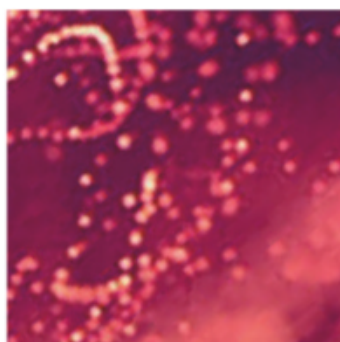
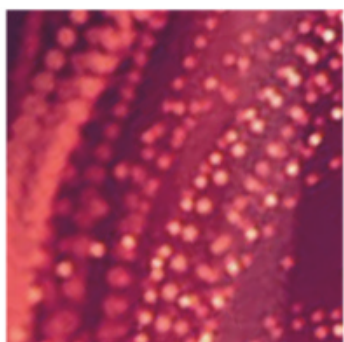
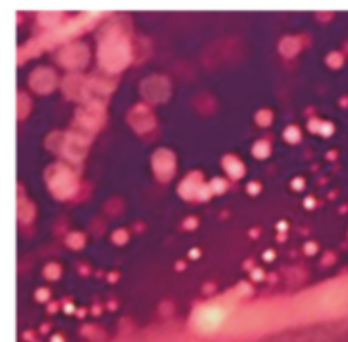
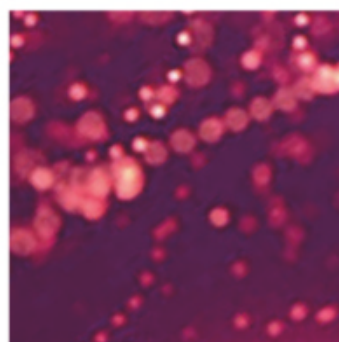
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How to be
human in the age
of the machine



Tim Peake
To the ends of
the Earth and
beyond



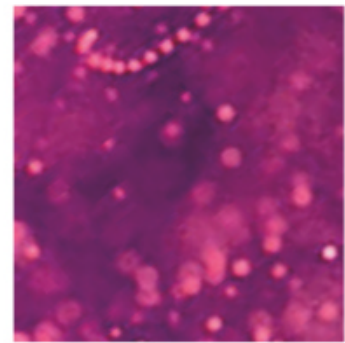
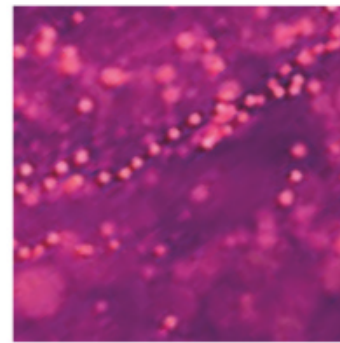
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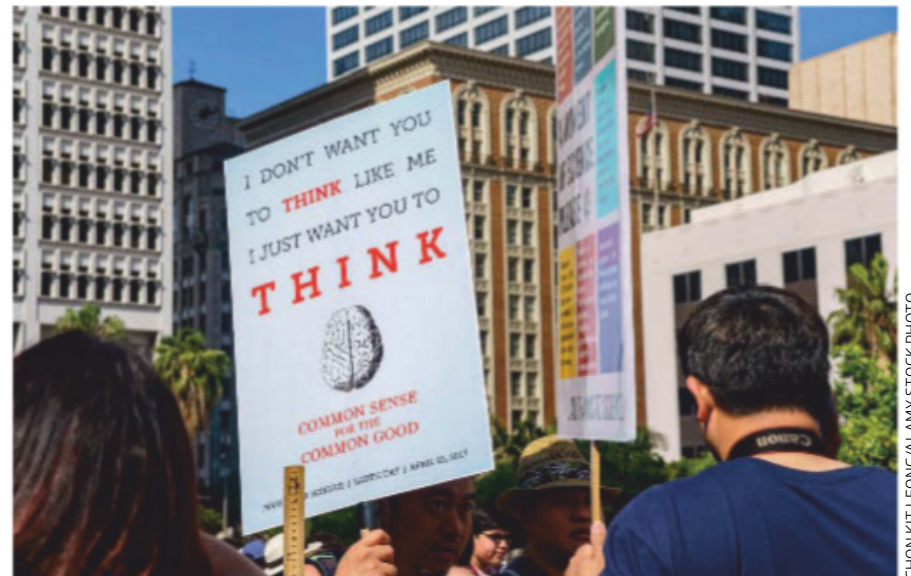


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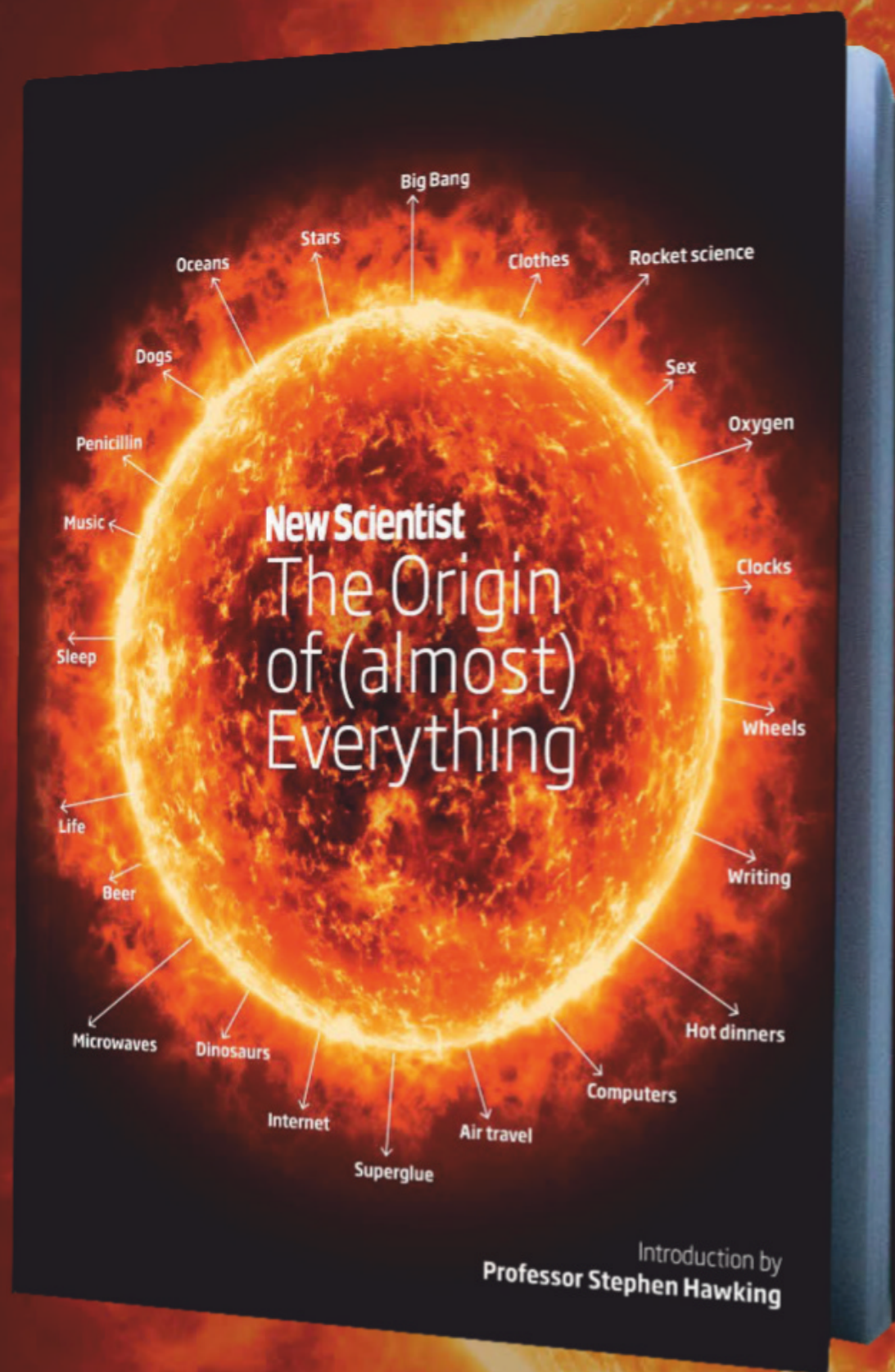
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Earth rising

Amid all the grim news, science is still making our world better

THIS has not been a year to fill the heart with hope. In the US, we have a president who lies apparently without consequence; in countries like Yemen, children are starving; in Europe, we have the omnishambles that is Brexit. And all these stories are stalked by the new horsemen of the climate apocalypse. Many of those involved in the science of climate change are gloomy in public, but even more gloomy when the microphones go off.

All that said, there are good, data-driven reasons to be hopeful as we prepare to welcome in 2019.

A robust reminder of this came earlier this year in *Factfulness: Ten*

reasons we're wrong about the world – and why things are better than you think, a brilliant book everyone should read. Its author, Hans Rosling – who died before the book came out – charts how the world is steadily becoming a better place to live as a human. There are outlier countries and regions: for example the Central African Republic, where violence and instability stall progress.

But overall – in terms of health, education, access to energy, clean water and sanitation, and a host of other markers – our species is going forward. We are psychologically geared towards thinking that everything is

getting worse. But actually the evidence says differently.

Much of this progress comes thanks to science and innovation, which underlines a fact that is probably obvious to any regular *New Scientist* reader: science and its applications have never been more important.

There are big things to worry about. There is no way to pretend that climate change and issues like biodiversity loss are going to be solved easily or quickly. But the lesson from *Factfulness* is that we are capable of amazing progress as a species. Here's to more steady (if barely noticed) human progress next year. ■



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FROM THE EDITOR

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PS *New Scientist* would be nothing without its wonderful readers: here's wishing you all a very happy holiday season.

Rethinking the origins of primates

Fossils suggest our order may have originated in Europe or America



JOEL SARTORE/NATIONAL GEOGRAPHIC

Michael Marshall

OUR distant primate ancestors are thought to have arisen in Asia, but new evidence challenges this assumption, suggesting primates may instead have evolved in Europe or North America.

Primates include all lemurs, monkeys, apes and humans. The oldest confirmed primate fossils are about 56 million years old, so were formed 10 million years after the extinction that wiped out all dinosaurs except birds. This time is called the Palaeocene-Eocene Thermal Maximum because the average global temperature rose by 5°C or more in a few thousand years. Many ocean species died out, but life on land flourished. Primates emerged, as did the first hoofed mammals.

The established story has been that primates appeared at this time in Asia, says anthropologist Paul Morse. This is based on the

discovery in China of several fossils of primitive primates that resemble miniature monkeys or bushbabies. These include *Archicebus achilles* as well as *Teilhardina asiatica*, which is thought to be one of the earliest primates.

But other *Teilhardina* species

We share an ancestor with lemurs, but we don't know what it was

have been found elsewhere, and seem to be just as old. These include *Teilhardina belgica* in Europe and *Teilhardina brandti* and several other species in North America.

To better understand early primates, Morse – while working at the Florida Museum of Natural History – and his colleagues collected 163 new *T. brandti* fossils from the Bighorn Basin in Wyoming, and compared them with other *Teilhardina* species (*Journal of Human Evolution*, doi.org/cxx9).

“What we found, once we had evaluated the variation within *T. brandti*, was that it closely resembled the animal from China [*T. asiatica*],” he says. “*T. belgica* also has some of these characteristics. They’re all about on par with one another in their primitiveness.”

That means *T. asiatica* cannot be reliably distinguished from either Europe’s *T. belgica* or North America’s *T. brandti*.

If we can’t determine which fossil is the most primitive,

we also can’t tell where primates evolved. Morse emphasises that he isn’t claiming North America is their cradle, rather than Asia, but that the question remains open.

However, Christopher Beard at the University of Kansas, who co-discovered *A. achilles*, argues that primates must have arisen in Asia, by process of elimination. “There’s nothing in either Europe or North America that’s a likely

“Wherever primates began, the group spread remarkably rapidly once they had emerged”

ancestor for these things,” he says. “So I think most of us have basically given up on Europe and North America being places where these animals might have originally evolved.” He points to Asian groups of tree shrews and the lemur-like gliding colugos as potential ancestors of primates.

But Morse thinks that the extinct plesiadapiforms – a large group of squirrel-like animals that lived in Asia, Europe and North America – could have given rise to the first primates. “Some aspects of their teeth closely resemble the teeth of early primates,” says Morse. A few plesiadapiforms seem to have adaptations in their ankles that closely resemble features seen in early primates that are thought to have been used for grasping, he says.

Regardless of where primates began, the group spread remarkably rapidly once they had emerged. “How did they go from being nowhere to being on all three northern continents?” asks Morse.

He thinks the spread of forests, driven by the warmer climate, gave them an uninterrupted habitat through which to move. ■

TRACING OUR ORIGINS

Fossils have been crucial in understanding the history of primates. Here are four of the most important finds.

Purgatorius

These squirrel-like North American mammals suggest primates could have originated 66 million years ago, but many

dispute whether they are true primates.

Eosimias sinensis

The “dawn monkey of China” lived a little over 40 million years ago. Some claim it was the first simian, the group that includes monkeys, apes and humans.

Proconsul

Living in Africa around

24 million years ago, this was one of the first apes. Over the next 10 million years, apes diversified and spread, turning Earth into a real planet of the apes.

Sahelanthropus tchadensis

The oldest hominin fossil yet identified is at least 6 million years old and was found in Chad.

New insight makes CRISPR easier to use

A STORM of criticism met claims last month that a Chinese scientist has created the world's first genome-edited children. One reason is that the twin girls have unpredicted new mutations with unknown effects.

It now appears there is an easy way to ensure the CRISPR genome editing technique makes far more precise, predictable genetic mutations.

The term "CRISPR genome editing" is a bit of a misnomer. The method is most commonly used to disable genes by introducing mutations in a specific site – adding or removing one or more DNA letters. But exactly which mutations get introduced appeared to be random.

Paola Scaffidi of the Francis Crick Institute in London suspected these mutations might not be fully random. To find out, her team used the CRISPR technique to mutate 1500 genome sites in human cells growing in a dish, and found a simple pattern.

It appears the target sequence that the CRISPR Cas9 protein binds to before cutting the DNA is crucial. If the fourth DNA letter from the end is a G, the resulting mutation is indeed relatively random. But if it is an A, T or C the outcome is more predictable. For instance, if it is a T, in 9 out of 10 cells a single extra T is inserted at the target site (*Molecular Cell*, doi.org/cxx6).

If confirmed, the result means that the thousands of biologists around the world using CRISPR for research can make it far more precise and powerful simply by altering where the protein binds. It also greatly boosts the prospects for using CRISPR inside the body to treat all kinds of disorders.

However, safety questions remain. Earlier this year, Allan Bradley of the Wellcome Sanger Institute in the UK reported that in about 1 in 5 cells, CRISPR triggers very large deletions. Scaffidi's team didn't look for these large deletions, so it remains unclear whether her approach can be used to avoid inducing them. Michael Le Page ■



DANIEL K SCHWEITZER/PLAINPICTURE

Chip with a nose will tell you when you have BO

DO I smell? It is an embarrassing problem we have all had to deal with. A run for the bus or a hot meeting room can leave you trying to check your armpit without anyone noticing. Luckily, AI is here to help.

UK chip-maker Arm, better known for developing the hardware that powers most smartphones, is working on a new generation of smart chips that embed artificial intelligence inside devices. One of these chips is being taught to smell.

The idea is that the chips will be small and cheap enough to be built into clothing, allowing an AI to keep tabs on your BO throughout the day. Arm also wants to add the chips to food packaging to monitor freshness.

The e-noses are part of a project called PlasticArmPit, in which Arm is developing smart chips made from thin sheets of plastic. Each chip will have eight different sensors and a built-in machine learning circuit.

It will look like a piece of cling-film with bits stuck to it,

says James Myers at Arm.

"PlasticArmPit will be the first application of machine learning in plastic electronics."

Smells are made up of different combinations and concentrations of gases. The sensors on the chip will detect different chemicals in the air and the AI will take that complex data and identify it as a particular whiff.

The chip will then score the smell. If it is in the armpit of your shirt, it will tell you the strength

"The chips will be small and cheap enough to be built into clothing, allowing an AI to keep tabs on your BO"

of your body odour from 1 to 5, says Myers. "It's the job of the machine learning to collect and interpret all the data and then alert the user if action is needed."

E-noses are not new. Julian Gardner, who pioneered the technology at the University of Warwick, UK, has been building them for three decades. In 1993 he co-founded a company called

An AI-powered chip could analyse the smell of your sweat

Alpha MOS that sells e-noses to the food industry.

The trouble is that these devices cost around \$20,000, says Gardner. He has since developed smaller, cheaper versions that cost just a few dollars. But they need to be made even cheaper to be sewn into clothing, which is what Arm hopes to do.

"I think that if the sensors are almost free, then people could buy clothes with them," says Gardner. But they will also need to survive in the wash, which could be a challenge even for plastic electronics, which are normally more resilient than regular electronics.

Alex Bond at Fresh Check, a London-based start-up that is developing a chemical test to check for bacteria on food, thinks e-noses are a good way to monitor food quality because they do not need to touch the food.

An AI-powered nose could also be tuned to pick up different types of smell. "Flexibility is important because beef doesn't spoil in the same way as fish," Bond says. "And a pork loin may be classed as spoiled, but still be suitable to be turned into sausage."

However, Bond thinks that it will be a challenge to get smart chips into food packaging – no matter how cheap they are. "Any increase to packaging costs is hard to justify," he says. "Most food manufacturers have exceptionally tight profit margins, so there has to be an incredibly strong incentive for them to adopt more expensive packaging."

One option may be to limit the use of sensors to premium foods or countries where there is a higher risk of contamination.

Still, Arm hopes to embed more than just e-noses into packaging. Chips built into plastic could be used to signal what kind of plastic a bottle or wrapper was made from, for example. Douglas Heaven ■

NEWS & TECHNOLOGY

Stem cells could halt epilepsy

Clare Wilson

FOR people with severe epilepsy, no medication is effective – but a radical approach of implanting stem cells into the brain could stop seizures at their source.

The technique, which has so far shown promise in rats, would involve taking some of a person's own skin cells and turning them into embryonic-like stem cells in the lab. These can then be directed to become a kind of brain cell that damps down seizures.

Epilepsy arises when there is an imbalance between two different kinds of nerve cell in the brain; excitatory ones, which cause other cells to fire, and inhibitory ones, which block firing. Seizures result when excitation swamps inhibition.

For some people with epilepsy, the surge of excitation starts in one part of the brain, called the hippocampus, before spreading elsewhere. So Ashok Shetty at Texas A&M University and his

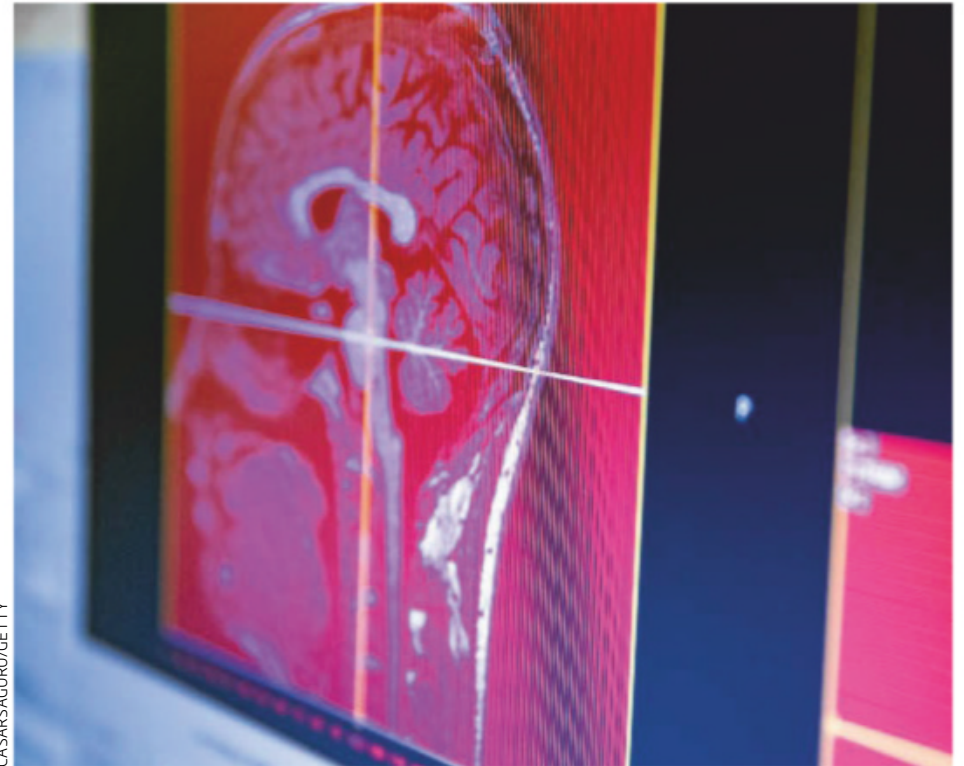
colleagues tried boosting inhibition at that site to see what would happen.

First, Shetty's team injected 38 rats with a chemical that triggers a long seizure. The resulting brain damage causes the animals to have spontaneous seizures, starting from the hippocampus, over the next few months.

A week after the initial damage, the team implanted inhibitory brain cells in the hippocampi of about half the rats. Five months later, those given implanted cells had 70 per cent fewer seizures than those without implants.

To check it was really the inhibitory cells working, five implanted animals were given cells that were genetically modified to stop firing when the animal was dosed with a drug. When under the drug's influence, these rats had about the same number of seizures as rats that hadn't had any cells implanted.

Dissections also showed that



CASARSAGURU/GETTY

Seizures are often triggered by activity in the hippocampus

the implanted cells survived in the hippocampus (*PNAS*, DOI: 10.1073/pnas.1814185115).

Shetty says the treatment could be suitable for people whose seizures originate in a small part of their hippocampus, and whose only other option is surgery to remove that part. They could try a cell implant instead, and if something went wrong, they could have all of the graft

removed along with the epileptic brain tissue. And if the therapeutic cells were made from a person's own skin, they wouldn't need medicines to stop rejection.

The study isn't proof this approach will work, though, says Bruno Frenguelli at the University of Warwick, UK. The rats were given implants soon after their brain damage, and it isn't clear if the technique would help people with seizures stemming from a head injury in the past, which is a common cause of epilepsy. ■

Pterosaurs had feathers to keep them warm

TWO spectacular fossils found in China show that the flying reptiles known as pterosaurs had primitive feathers to help keep them warm, just like many dinosaurs. The finding suggests that feathers evolved far earlier than we thought.

The wings of pterosaurs were made of muscles, fibre and expanses of skin, and had no need of flight feathers. The feathers they had are small and tufty.

"They are almost certainly just for insulation," says Mike Benton at the University of Bristol, UK, a member of the team that discovered one of the

fossils about two years ago. The second specimen was found several years ago but its importance is only now being appreciated.

Fossils found as long ago as the 1840s revealed that pterosaurs had fur on their head and bodies. Palaeontologists came up with the term "pycnofibres" to describe it, to distinguish it from the hair of mammals and the feathers of birds.

In the more recently discovered fossils, these pycnofibres are very well preserved. Much of the head, body and limbs of these pterosaurs were covered with hair-like filaments, just as we have long thought was the case. But the team also found three distinct types of branched filaments. "If your dermal fluff branches, that's a feather," says Benton.

For instance, one type is found on the wing membranes. It branches from the base and resembles down. All are remarkably similar to the feathers found on many dinosaurs (*Nature Ecology & Evolution*, doi.org/cxwm).

"I think it's now case closed: pterosaurs had feathers," says palaeontologist Steve Brusatte at the University of Edinburgh, UK.

There are two possibilities. Either very similar looking feathers evolved independently on at least four occasions: in pterosaurs, in theropod dinosaurs such as

velociraptors (which gave rise to birds) and in two groups of plant-eating ornithischian dinosaurs represented by *Psittacosaurus* and *Kulindadromeus*. Or they evolved in the common ancestor of all these groups.

The second explanation is the simplest. "That would take the origin back from about 170 million years ago to around 250 million years," says Benton.

"The most logical conclusion is that feathers go all the way back, beyond even dinosaurs, to a more distant ancestor," says Brusatte. "The next step out on the family tree is crocodiles, so maybe, just maybe, a palaeontologist will one day find a fossil croc with feathers."

Michael Le Page ■

"Maybe, just maybe, a palaeontologist will one day find a fossil croc with feathers"

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NEWS & TECHNOLOGY

FIELD NOTES Devon, UK

Walking in a beaver wonderland

Graham Lawton

I HAVE gone back in time to a landscape not seen in this corner of the world for the best part of 500 years. All around me are signs of intensive engineering – not by humans, but by beavers.

Mark Elliott at the Devon Wildlife Trust is showing me round 2.8 hectares of wetland on the edge of Dartmoor, UK, where in 2011 the trust released a pair of Eurasian beavers. “They’re really busy at the moment,” he says.

Before the release, the area was a scrubby woodland with a small stream running through it. But the beavers quickly got to work, building a lodge, deepening the pond around it and damming the headwaters of the stream.

Elliott and his colleagues collated the results of the beaver introduction earlier this year, including the huge impact they have had on flood management.

The area sees a lot of rain, and water runs quickly off the surrounding land, surging into rivers and causing flash floods. But on beaver territory, the water is now held up in ponds, flowing out at a far more leisurely pace. “It takes days or weeks,” says Richard Brazier at the University of Exeter, UK, one of the project’s lead scientists. Even during a downpour, the outward flow of water barely rises above baseline.

Hardly anybody lives nearby, so flooding isn’t an issue. But it is a serious and growing menace elsewhere. The UK has earmarked £2.5 billion a year to upgrade its flood defences. Judging from the

research done here, beavers could be part of the solution.

These creatures are known as ecosystem engineers. I can see signs of ceaseless beaver engineering across every inch of the site: felled trees, gnawed stumps, chewed logs and sticks stripped of bark. The stream has been turned into a series of 13 large pools held back by dams made of sticks, mud and grass. The oldest dam resembles a Neolithic earthwork, several metres across and grassed over. It holds a serious amount of water. In total, dams on the site hold more than a million litres.

Biodiversity boom

Radiating out from the pools are long, deep canals that the beavers use to move around their territory. Their activity has opened up the dense thicket and biodiversity is booming. Compared with the monotony of the surrounding farmland, it is stunningly beautiful. “The British landscape would have looked very different when it had beavers in it,” says Elliott.

The team has kept the location



KIRSTIN KIDD

of the project secret to avoid people interfering. Some are just keen to see the beavers for themselves, but others may wish to sabotage the trial because they oppose the reintroduction of a “nuisance” species.

Beavers used to be common across Great Britain but were hunted to extinction for their fur, meat and scent glands. The last written record of a wild beaver in England dates from 1526. It has taken half a millennium to fully realise what we lost.

There is no doubt that beavers can be a nuisance by blocking storm drains and gnawing down the wrong trees. But this can be

easily managed, says Elliott. For example, the animals can be fenced in, as the trust has done.

Halfway down the stream is beaver HQ – the lodge. Unfortunately, this is not a good time of year to spot beavers. Although winter is when they are busiest, beavers are nocturnal and secretive, meaning that it is dark before they get moving.

Nevertheless, we squelch past the lodge knowing they are asleep inside. Their musty scent hangs in the air. Close, but no beaver.

As we drive away from beaverland, Brazier points out flood defences that have recently been built to protect Exeter city centre. More will be needed as climate change kicks in and rainfall increases. Brazier laments that the government has set aside £15 million for natural flood management, but not a penny for beaver reintroductions.

That may change soon. Despite being a native species, in England and Wales, beavers are currently classed as “not normally resident” and require a licence to be released. But under pressure from Brazier and others, the government is reviewing these rules. Environment secretary Michael Gove is said to be receptive. ■

John Morgan loaned his land to beavers (near right). Rare sighting of a *New Scientist* writer (far right)

MARK ELLIOTT/DEVON WILDLIFE TRUST

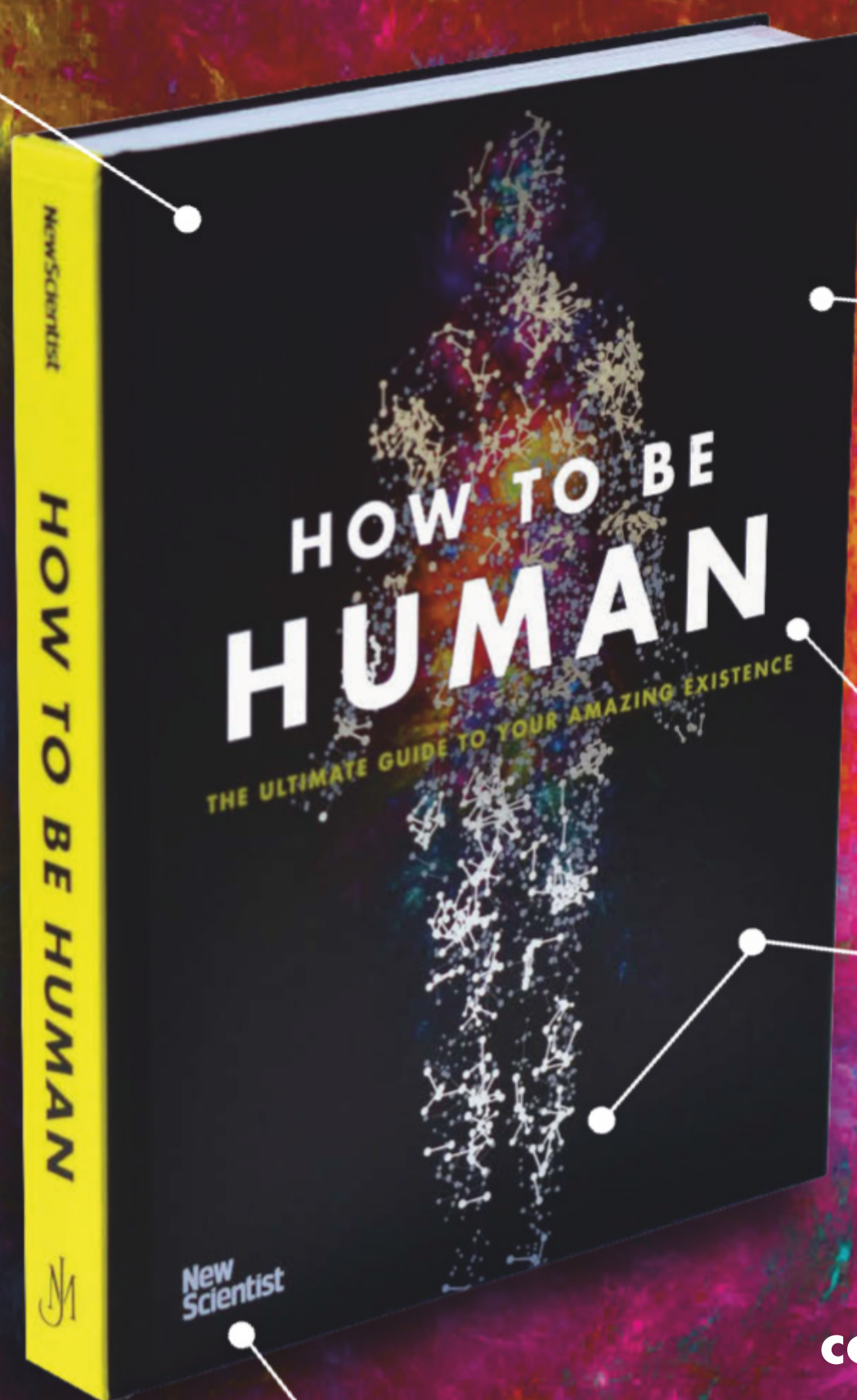


KIRSTIN KIDD



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People lying down solve anagrams in 10% less time than people standing up.



About 6 in 100 babies (mostly boys) are born with an extra nipple.

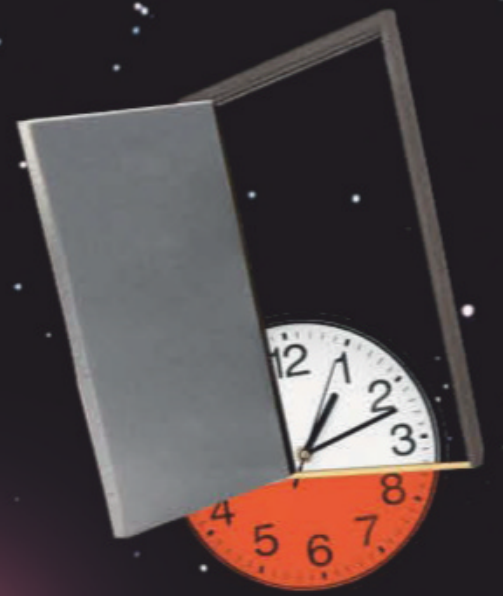
60% of us experience 'inner speech' where everyday thoughts take a back-and-forth conversational style.

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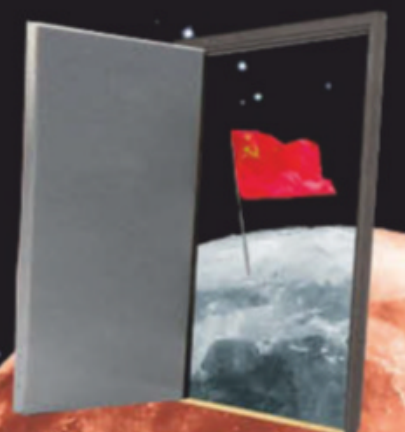
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NEWS & TECHNOLOGY

Alzheimer's link to child hormone jabs

Chelsea Whyte

GROWTH hormones given to children decades ago seem to have spread proteins linked to Alzheimer's disease.

Between 1958 and 1985, approximately 30,000 children around the world received injections of human growth hormone extracted from the pituitary glands of dead people. These were used to treat genetic disorders and growth deficiencies.

Three years ago, while looking at the brains of eight people who had such injections and later died of the rare brain disorder Creutzfeldt-Jakob disease (CJD), John Collinge at University College London and his colleagues noticed they all had beta-amyloid proteins in their brains.

Beta-amyloid is known to accumulate and form sticky plaques in the brains of people

proteins, which are implicated in Alzheimer's too.

The growth hormone used by the eight people who died of CJD was extracted from cadavers using one particular method. So Collinge and his team also looked at growth hormone prepared from cadavers using three other methods, and found no sign of beta-amyloid or tau proteins.

To see if exposure to the growth hormone with the proteins could seed later disease, the team injected samples of it into the brains of mice engineered to be able to develop some human-like signs of Alzheimer's disease.

These animals went on to accumulate beta-amyloid and tau proteins in their brains. Mice similarly injected with modern, synthetic growth hormone, however, had no signs of these proteins (*Nature*, doi.org/gfpntg). Together, the results suggest that some formulations of growth hormone from cadavers can indeed seed the build-up of Alzheimer's-related proteins.

There have been other hints that Alzheimer's proteins can persist and spread. One study found that eight people who had cerebral amyloid angiopathy at a young age – a build-up of beta-amyloid in the brain that can lead to bleeding – had all had childhood brain surgery, and that surgical instruments may transmit these proteins.

The persistence of beta-amyloid may explain why its build-up in the brain is troublesome, says David Holtzman at Washington University in St Louis, Missouri. "These proteins are stable once they form, often for the lifetime of the individual. Once these things form, they continue to grow and grow, and the body can't get rid of it easily," he says. ■

"Once Alzheimer's proteins form, they continue to grow, and the body can't get rid of them easily"

with Alzheimer's disease. These eight people didn't have Alzheimer's, as they all died from CJD at a young age, but Collinge says that had they lived, the presence of beta-amyloid suggests it is possible that they would have gone on to develop the illness.

The team wondered whether growth hormone itself stimulates the accumulation of beta-amyloid proteins or if the hormones were contaminated with this protein. To investigate, Collinge and his team examined samples of the growth hormone given to these eight people, which had been archived in the UK. They found beta-amyloid proteins in those samples. Also present were tau



BERTRAND LEFEBVRE

Bizarre fossils identified as early starfish relatives

MYSTERIOUS ancient animals that have confused us for years have revealed their true identity: they are the ancestors of starfish.

Stylophorans are an extinct group of early complex creatures that appeared soon after animal diversity first exploded 541 million years ago. Nailing down their place on the tree of life is now possible thanks to the discovery of better fossils (pictured).

Previous fossils looked a little like an arrow, if the arrowhead was very large compared with the shaft. This led to three schools of thought on what they were. One view was that the "shaft" is a tail, in which case they looked a bit like tadpoles, suggesting they were closely related to animals with a backbone.

However, those fossils also look a bit like echinoderms, the group of marine life that includes starfish. In that case, the shaft may be a feeding arm. The difficulty with this idea is that stylophorans only had one arm, whereas starfish typically have five.

Finally, some biologists thought they looked like hemichordates, a group of worm-like sea creatures closely related to echinoderms.

Although they appear different today, echinoderms, backboneed animals and hemichordates all belong

to a wider set of living things called the deuterostomes, and would have looked relatively similar early in their evolution. Stylophorans were often considered very early deuterostomes, which meant they could fit into any one of the three groups, but no one could agree which one.

"It wasn't obvious at all," says Bertrand Lefebvre of Claude Bernard University Lyon, France. He and his colleagues suggest the debate is now settled. They have unearthed thousands of new stylophoran fossils in Morocco, including some whose soft tissues have been preserved.

These reveal that stylophorans had additional echinoderm-like traits not been seen before, including the watery echinoderm equivalent of the human circulatory system. "We have blood, echinoderms have seawater," says Lefebvre (*Geobios*, doi.org/cxww).

The finding will force a rethink of the early evolution of animals, Lefebvre says, because stylophorans have often been held up as an example of very early deuterostomes. He says they are too far evolved as echinoderms for that to be true, which leaves the events that occurred early in deuterostome evolution something of a mystery. Michael Marshall ■

NEWS & TECHNOLOGY

Quantum network links four people

Chelsea Whyte

THE quantum internet is starting small, but growing. A prototype lets four people communicate simultaneously through channels secured by the laws of quantum physics, and it could be scalable.

Sören Wengerowsky at the University of Vienna and his colleagues devised a network that uses quantum key distribution (QKD) to keep messages secure.

The general method relies on two entangled photons – particles of light with their quantum properties linked. Users get a photon each and use them to generate a secure channel. Any would-be hackers will disturb the fragile quantum state, revealing their presence to the users who can then abandon the channel, preventing any eavesdropping.

QKD systems often link the photons' orientation, but the team chose to entangle a different property: the frequency of their light. Since this can take many values, it could be tuned to allow connections with several users.

The team created the entangled photons with a laser, then split them into 12 separate channels,

each with a different frequency.

Their four users – Alice, Bob, Chloe and Dave – were connected through fibre optic cables that each had three channels. So, for example, Alice had a secure line to Bob, Chloe and Dave (*Nature*, doi.org/gfpjpp).

These private lines eliminate the need for communications to pass through a central hub, and

because the system operates on standard telecommunications equipment, it should be easy to roll out on existing networks, says Wengerowsky.

"If you want to scale the network up, you just add the hardware required for one of the users," says Robert Ursin, who was part of the team that built the new system. In other words, it is easy to just plug a new user right into the network. "It's much like the classical internet where everyone gets a router."

The laws of quantum physics can make communications secure

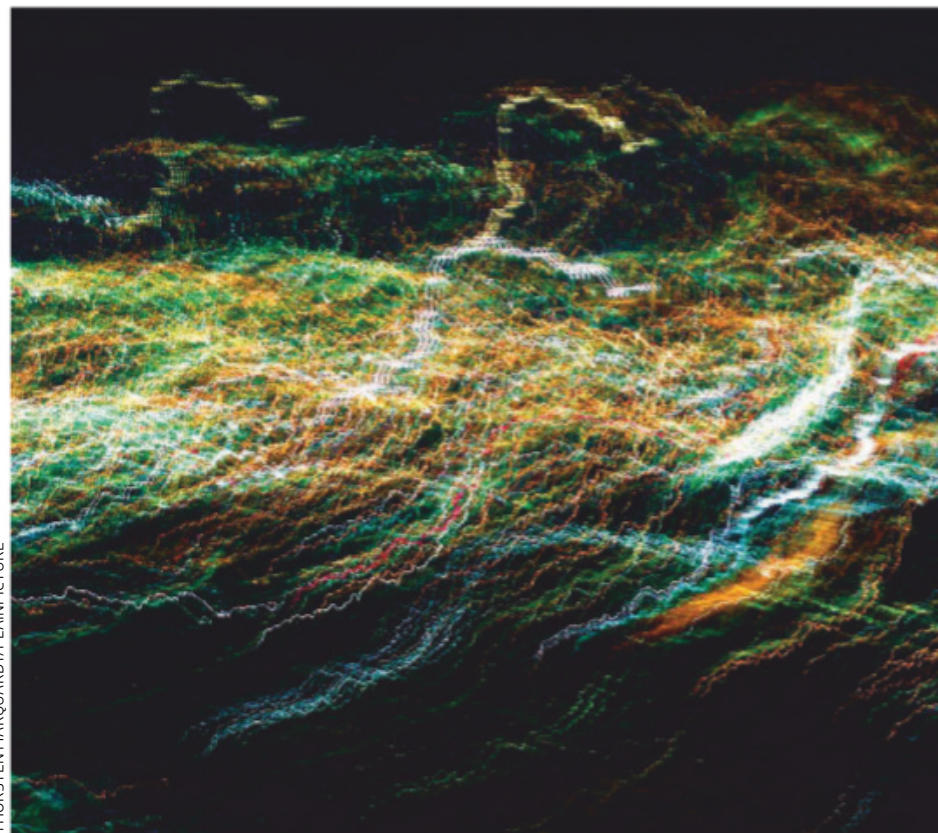
Some other types of quantum networks require so-called trusted nodes, through which all communications must pass, but these are vulnerable to attack, reducing the benefits of quantum security. Or they may need active switches made of mirrors that direct the information flow like railroad switches, and could be subject to failure. This system doesn't use any of those things, which will make it easier to scale.

"This is a nice demonstration because it's all passive optics, so in that sense it's very manageable," says Thomas Jennewein at the University of Waterloo, Canada. He hopes it will help make quantum key distribution more mainstream.

He adds that although it may be simple enough to add another fibre when you introduce a new user, at some point there is a limit to how many times you can split the frequencies of light to create additional channels.

"The entanglement quality could start degrading as more and more channels are combined into one fibre, or the detector system might get overwhelmed at some point," he says.

Ursin says that in the future, they could potentially take advantage of more properties of the photons – their polarisation, for instance – to encode more information into the quantum keys to make them more secure. ■



THORSTEN MARQUARDT/PLAINPICTURE

Moon dust may be toxic to human lungs

THE surface of the moon is dusty – and nasty. The Apollo astronauts quickly learned that the sharp grains of moon dust could tear spacesuits and irritate their lungs, but now it seems the lunar surface is even worse for human health than we thought.

By studying lunar dust samples brought back by astronauts, we discovered that they contain certain

minerals that are known to quickly react with human cells and generate toxic hydroxyl radicals. These hydroxyl radicals have previously been linked to lung cancers.

To estimate how many radicals would be produced in humans after exposure to lunar dust, Donald Hendrix at Stony Brook University, New York, and his colleagues took dust from two iron-rich minerals – olivine and augite – found on the moon, and soaked it in a liquid that simulates human lung fluid.

After 15 minutes, the two minerals had released about nine times more

hydroxyl radicals per litre of fluid than quartz dust, which is highly toxic.

"The fine metallic iron is extremely hazardous to human health," says Hendrix.

Because our supply of lunar dust is limited, the study used similar rock dust found on Earth, which contains a smaller concentration of reactive minerals, he says. So, the damage from real lunar dust may

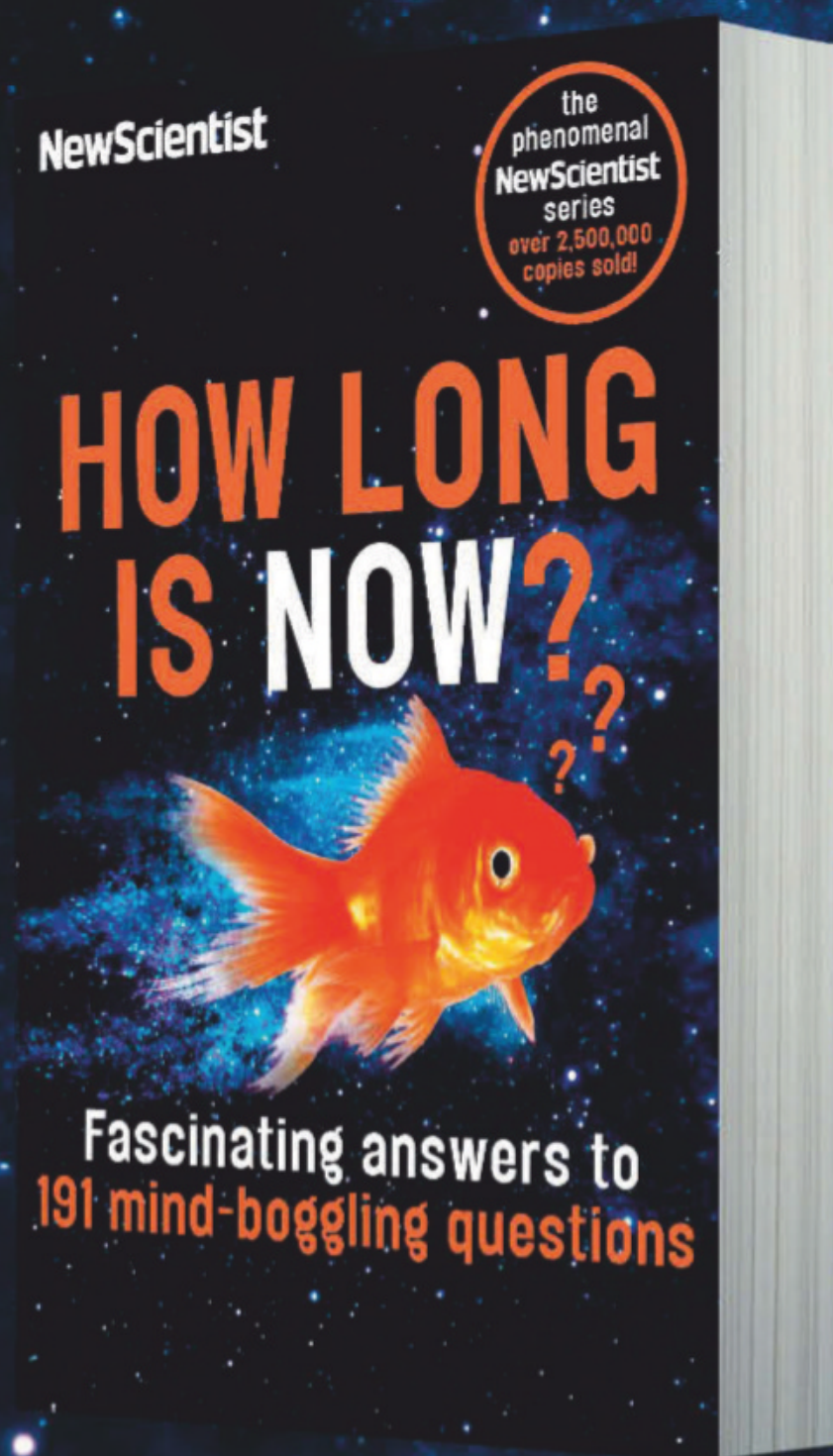
"The fine metallic iron is hazardous to human health. It's a major health concern for astronauts"

be more severe.

"It's a major health concern for future astronauts," says Hendrix, who presented the work at the American Geophysical Union meeting in Washington DC last week.

Cort Anastasio at the University of California, Davis, says that it isn't enough to just look at simulated lung fluid – further research is needed to determine the dust's toxicity to real human lungs. "Our lungs have defences against these free radicals, so it's difficult to assess the toxicity of a given amount of hydroxyl radicals," he says. Yvaine Ye ■

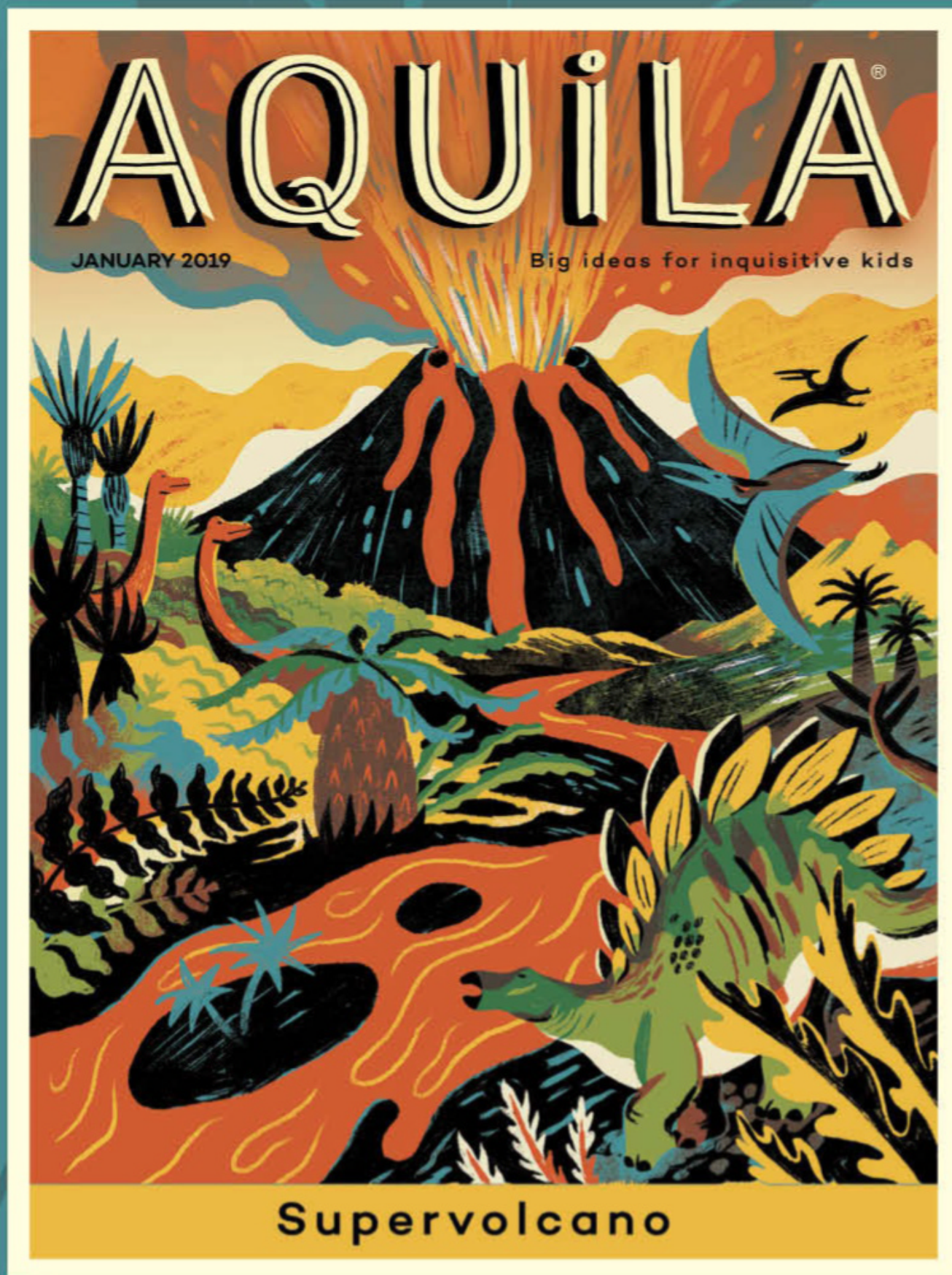
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IN BRIEF

TRAVELMUSE / ALAMY STOCK PHOTO



Macaques soothed by the sight of a pamper session

MONKEYS become more relaxed just watching other monkeys grooming each other, a finding that could explain the popularity of online "head orgasm" videos.

Stuart Semple at the University of Roehampton in London and his student Juliette Berthier studied 20 female Barbary macaques in a semi-free ranging group in a safari-park-like environment in a UK forest.

When a macaque saw another being groomed, it started performing fewer "self-directed" behaviours such as scratching and yawning. These are thought to be signs of anxiety, so it seems the macaques were less anxious.

The phenomenon is similar to "emotional contagion": humans become more cheerful if we meet someone cheerful, even online, and some parrots start playing when they hear other parrots making playful sounds. But in this case the effect lasted longer, in some cases for 30 minutes (*Proceedings of the Royal Society B*, DOI: 10.1098/rspb.2018.1964).

The finding may help explain the phenomenon of autonomous sensory meridian response, known as ASMR. In this, people may get a pleasant, head-tingling sensation when watching videos of other people that include comforting gestures and gentle speech.

"If you look at what sorts of behaviours tend to trigger ASMR in people, they're basically grooming," says Nick Davis of Manchester Metropolitan University in the UK.

The lion of Oz was a fearsome thing

AUSTRALIA'S extinct "marsupial lion" was unlike any animal living today, shredding its prey like a Tasmanian devil, biting like a lion, and climbing like a koala.

Rod Wells at Flinders University in Australia and his colleagues carried out the most detailed reconstruction yet of *Thylacoleo carnifex* to better understand the mysterious creature. It would have measured more than a metre

long and more than half a metre tall while on all fours, weighing about 100 kilograms. It carried its young in a pouch.

Comparisons with living Australian marsupials suggest that *T. carnifex*, which vanished about 45,000 years ago, was most similar in appearance to the Tasmanian devil, but would have been about 10 times the size. It had the same stiff back and

strong, rigid tail that Tasmanian devils use for balance while tearing apart prey with their paws and teeth, says Wells.

The wear patterns on its teeth suggest it was a carnivore that cut and swallowed prey without chewing, with a similar bite force to that of an African lion. The structure of the marsupial lion's forearms, along with its strong collarbones and large thumb claw, suggest that it climbed like a koala (*PLoS One*, doi.org/cxwn).

DNA search sheds more light on acne

THE discovery that variants of genes influencing hair follicles may have a link to acne could lead to new treatments.

That's the hope of a team, led by Jonathan Barker at the National Institute for Health Research, UK, that studied the DNA of 27,000 people, including more than 5000 with severe acne. They found genetic differences that were more common in those with acne.

Barker and his colleagues found that many of these differences were in genes that influence hair follicle formation and activity. There have been few advances in acne treatment for decades. Barker hopes the genetic clues could lead to better drugs (*Nature Communications*, doi.org/gfphsj).

Acne affects 80 per cent of people aged from 11 to 30. The most effective treatment now is isotretinoin, but it has significant side effects, including birth defects if taken during pregnancy.

Honey, we shrunk Alice in Wonderland

MAKING minuscule objects is hard, so a new 3D printing method called implosion fabrication just shrinks bigger stuff instead.

Simple nanostructures can be made in layers using 3D printing, but not more complex structures. Ed Boyden at the Massachusetts Institute of Technology and his colleagues previously developed a method for magnifying a small structure by embedding it in a material and expanding it.

They have now reversed this, using centimetre-sized structures built on a polyacrylate scaffold by sticking molecules to anchor points. These structures were then shrunk to a cubic millimetre by applying acid. Objects created include a tiny *Alice in Wonderland* etching (*Science*, doi.org/cxx8).

They will know us by our fowl diet

IF HUMANS vanish, one of the most enduring records of our time on Earth will be the sudden upsurge in the fossil record of chicken bones.

Geologists have proposed that the age of humans constitutes a new epoch in Earth's history, known as the Anthropocene. The explosion in chicken farming and rapid change in the bones of the birds because of selective breeding make their remains an ideal sign of our time.

Carys Bennett at the University of Leicester, UK, says this will eventually result in a layer of fossils that are indicative of our existence. They will stand out, by their sheer numbers and because the modern chicken is different from its wild ancestor, especially since intensive farming took off in the 20th century.

Bennett and his colleagues found the leg bone of a juvenile broiler is now triple the width and twice as long as that of its wild forebears.

The timing of these changes coincides with other proposed signs of the Anthropocene, such as plastics, fertilisers, fossil fuels and radioactive deposits.

Most chicken bones are thrown into landfill, where the conditions tend to mummify organic matter. That means they have the potential to fossilise and remain preserved for millions of years, says Bennett (*Royal Society Open Science*, DOI: 10.1098/rsos.180325).



JOHN KUCZALA/GETTY

Teens score better grades when they get up later

A LIE-IN on school days improves the quality of students' sleep, leading to a boost in attendance and academic performance.

A US study has become the first to show this objectively, using activity monitors to gauge rest duration, rather than relying on students to recall snoozing habits.

Teenagers tend to prefer late nights and lie-ins due to body-clock shifts that occur during puberty. However, this preference doesn't align with the early start times of most schools. To address this problem, middle

and high schools in Seattle decided to delay their start from 7.50am to 8.45am from mid-2016.

Horacio de la Iglesia at the University of Washington and his colleagues measured the impact at two schools. They compared 94 students aged 15 or 16, taking a biology class before the change with 84 taking it afterwards.

According to activity monitors worn on their wrists, both groups went to bed at around the same time. But because they were able to get up later, the second batch of students snoozed for an extra

34 minutes per day on average.

This extra sleep was correlated with greater daytime alertness and 5 per cent higher grades in the second semester, on average. This may be because sleep plays a key role in learning and laying down memories, says de la Iglesia.

At one of the schools, class attendance also improved. Students in the later-start group were late on two fewer days and had two fewer absences per year on average than the students who had to start classes earlier (*Science Advances*, doi.org/cxwd).

Young reef builders love a fishy rumble

CORALS seem to appreciate noisy neighbours. Free-floating coral larvae are more likely to settle on a surface if the water is alive with the rumbling noise of a healthy fish population. The finding could help efforts to restore reefs.

Coral larvae drift, looking for a place to call home. Light influences where they settle, but to discern the effect of noise, Amy Apprill at the Woods Hole Oceanographic Institution in Massachusetts and her colleagues sealed equal numbers of mustard hill coral larvae in 18 containers of filtered seawater.

The team put the boxes in the Caribbean: six on a healthy, fish-abundant reef, six on a less robust reef and six at a barren site. All three sites have similar light but different sound environments. A healthy reef's large fish create louder low-frequency sounds.

After two and a half days, the team found at least 50 per cent more of the larvae had settled in the healthy reef site compared with those at the other two reefs (*Royal Society Open Science*, DOI: 10.1098/rsos.181358).

Apprill suggests we could play back healthy reef sounds on sites we want to restore.



NASA/GODDARD/UNIVERSITY OF ARIZONA

Distant space rock gives up its secrets

NASA'S visit to the asteroid Bennu has revealed it is full of water, covered in boulders and riddled with caves. Those are the first findings from the OSIRIS-REx mission.

Initial images showed a body shaped like a spinning top, with a raised ridge around its centre and an average diameter of about 500 metres. Now that the probe is closer, we can see the surface is covered in hundreds of large rocks, more than expected. That may make landing to get a dust sample harder. It looks like the rocks have a mix of compositions, said Dante Lauretta at the University

of Arizona, who leads the mission.

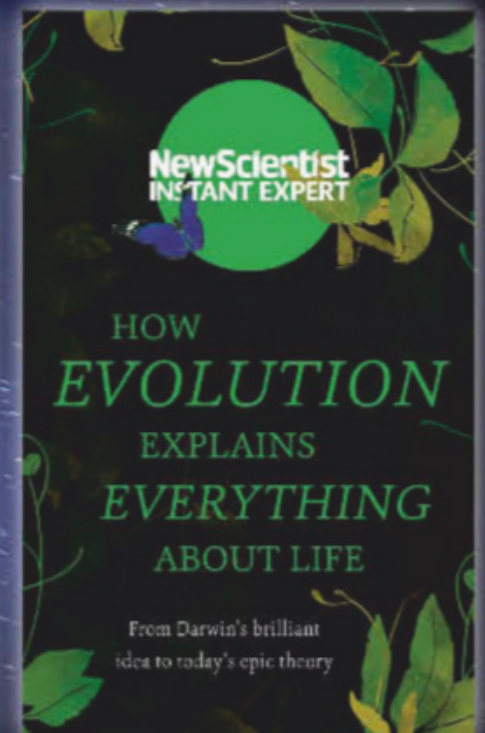
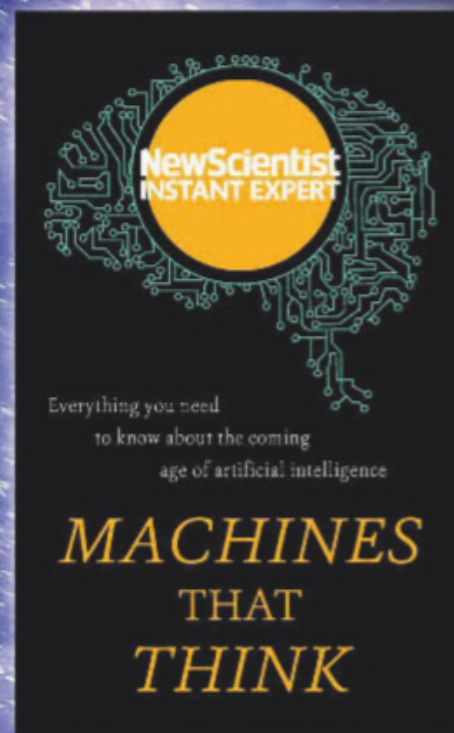
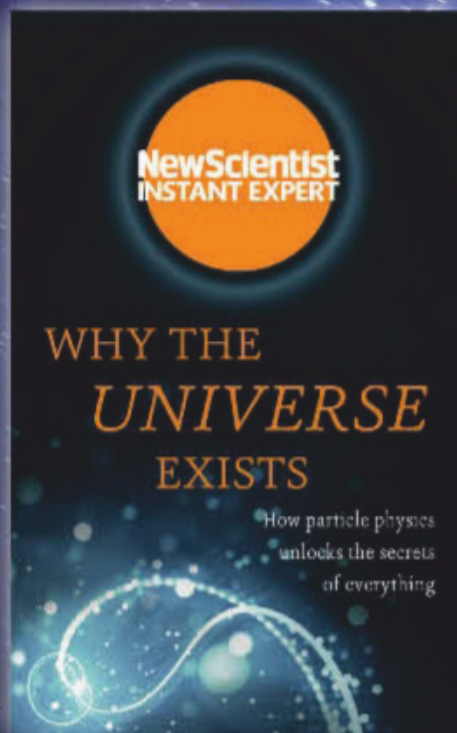
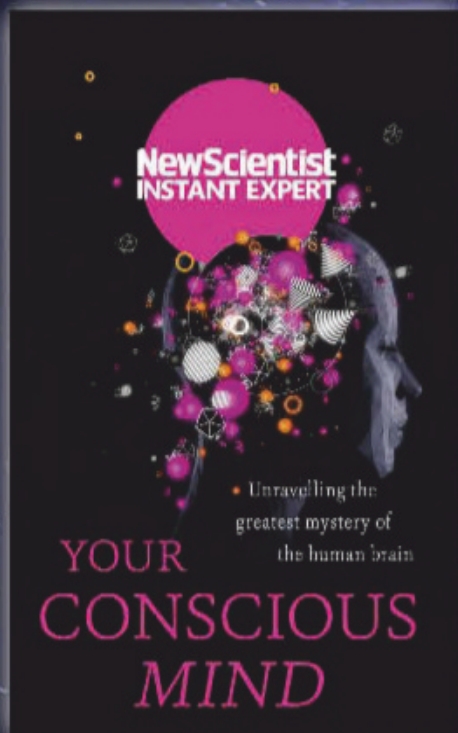
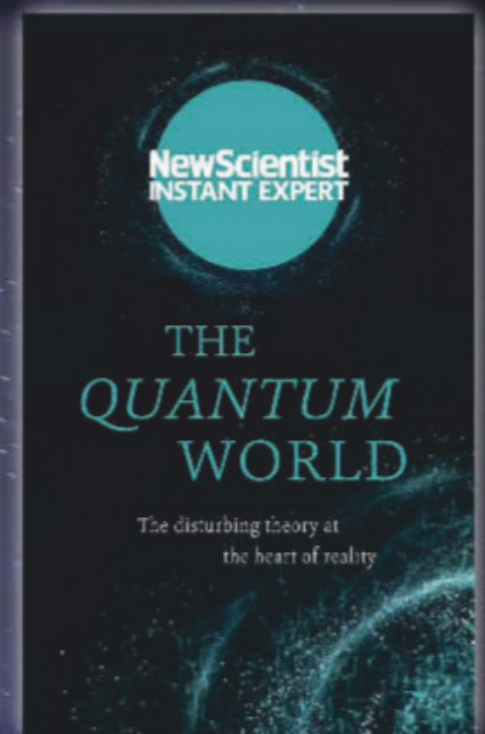
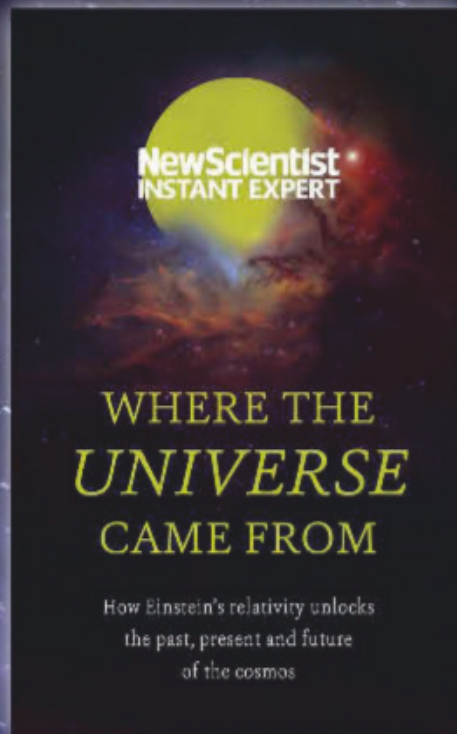
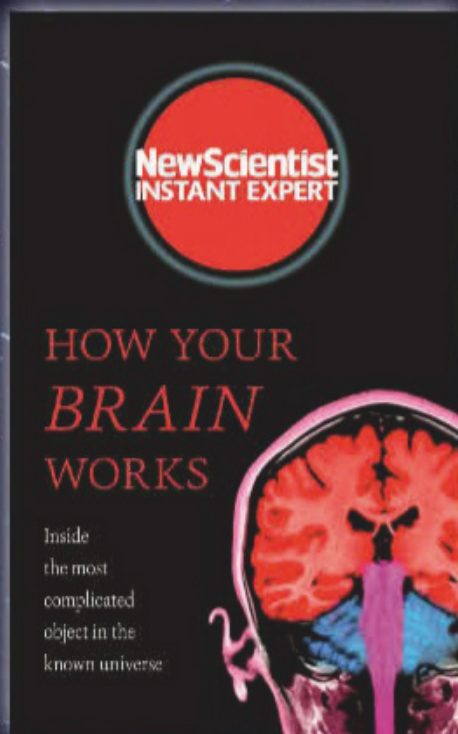
Bennu is also less dense than expected, indicating it is very porous. Up to 40 per cent of its volume may be pores and caves, said Lauretta.

The first measurements of the asteroid composition showed strong evidence that much of its surface is covered in hydrated minerals, rocks with water locked in their structure.

This is a good sign for asteroid mining, as water is expected to be one of the most in-demand products. It might also help us figure out how water and other ingredients for life got to Earth early in its history.

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INSIGHT SCIENCE DENIALISM

Pass the facts, would you?

Changing someone's mind at the dinner table is no easy task.

Michael Le Page explores the best way to correct scientific myths

FAMILY gatherings can bring up contentious topics we prefer to avoid, and with the festive season in full swing, it might be hard to dodge your more science-averse relatives. At some point, you know they will start spouting falsities, such as: "HIV doesn't cause AIDS", "Genetically modified foods are not safe to eat", "Climate change is a conspiracy" or "Vaccines cause autism". (Again, all these statements are untrue.)

If this happens, you don't have to just sit there quietly fuming. "Is it worth making an effort to correct people?" says Jason Reifler at the University of Exeter, UK, who studies ways of challenging misperceptions. "I think so."

Obviously, it is inherently more difficult to refute false beliefs than to spread them. Anyone can parrot a lie, but it usually takes a bit of time and knowledge to explain why a statement is wrong.

Take a classic: "The climate has always changed, it's nothing to do with humans." To counter this, you

Science after arguing with his father-in-law. For instance, the "climate is always changing" myth is like claiming that because people have always stolen from each other, leaving your house unlocked won't up the risk of burglary.

But you need to beware the backfire effect. This is the idea

Getting people to believe you often takes more than just stating facts

that trying to change someone's false belief can make them believe it more strongly. It shot to fame a decade ago when Reifler and a colleague looked at why people continued to believe that Iraqi dictator Saddam Hussein had weapons of mass destruction, despite none ever being found. When they tried to correct this belief in a group of people, they found that these efforts instead reinforced it in those

with a conservative outlook.

This was discouraging news for the fight against false beliefs. "The last thing you want to do when debunking misinformation is blunder in and make matters worse," wrote Cook and Stephan Lewandowsky at the University of Bristol, UK, in *The Debunking Handbook*, a short guide published in 2011.

However, more recent studies are far more encouraging. "It's not

"Anyone can parrot a lie, but it usually takes a bit of time and knowledge to explain why a statement is wrong"

need to explain how the world is now warming at an unprecedented rate, when otherwise it would be cooling slightly were it not for our carbon dioxide emissions. If you don't know the specifics, there are websites such as Skeptical Science that debunk common myths.

But sometimes there are shortcuts to make your point convincing. "Parallel" arguments can often highlight logical flaws very effectively, says John Cook of George Mason University, Virginia, who set up Skeptical



CHON KITTEONG/ALAMY STOCK PHOTO

as prevalent as we initially thought," says Lewandowsky.

In the handbook, he and Cook looked at three types of backfire effect. The simplest is the "overkill" effect, the idea that if you bombard people with too many counterarguments, they can't process all the information and end up believing the false facts more strongly.

But in a paper published in September, a team including Lewandowsky found that using four to six counterarguments led to at least as much belief reduction as using just two. "I think the overkill backfire effect is only an issue if you are using poor arguments," says lead author Ullrich Ecker at the University of Western Australia in Perth.

What does this mean for family arguments? If you are not sure of the facts, do some surreptitious web browsing on your phone rather than trying to wing it.

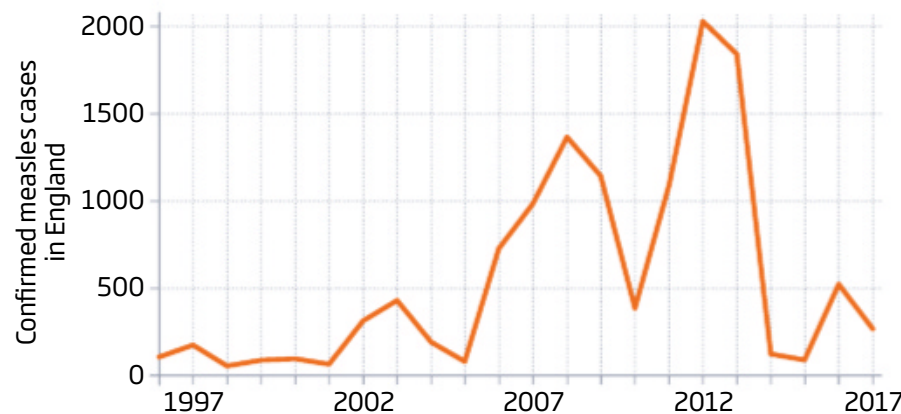
Truth sandwich

The second type is the familiarity backfire effect, the idea that just talking about a myth can reinforce belief. This led to some rather tricky advice: try to avoid repeating myths when refuting them. But again, recent studies don't back this up.

Still, if someone isn't paying attention, they could be left with the wrong idea. Suppose you are reeling off evidence that there is no link between vaccination and autism, such as the fact that the incidence of autism rose in Japan even when the MMR vaccine was temporarily withdrawn. If a bystander who has never heard of the issue catches only snippets of the conversation, they might end up with the false impression that there is a link.

So it is still safest to present a "factual wrapper" or "truth sandwich": start with the facts before mentioning the myth, then repeat the facts. You can see this in action around the falsehoods at the top of this article.

UK vaccination rates plummeted after media reports in the late 90s of a now-discredited study suggesting the MMR vaccine may cause autism. Eventually this led to a rise in cases of measles, showing the real-world impact of false beliefs



SOURCE: vk.org/oxac.uk/measles

Then there's the world-view backfire effect, the notion that if a correction clashes with your world view, it strengthens the misconception. Reifler found this in his Iraq study, but he points out that the effect only appeared in two out of five experiments.

What's more, although some later studies have seen similar results, many haven't seen the effect at all. This suggests it is much rarer than Reifler's work suggested, which he thinks is fantastic news.

So why the conflicting results? We don't know, but some people might be especially susceptible. According to one recent paper, belief in fake news is associated with "delusionality, dogmatism, religious fundamentalism, and reduced analytic thinking".

But whatever you do, don't point this out, or resort to outright confrontation or insults

HOW TO HAVE A GOOD ARGUMENT

DO

- Refute false beliefs
- Rely on strong facts
- Wrap false ideas in a "truth sandwich"
- Listen and ask questions that expose faulty logic

DON'T

- Insult people
- Try to wing it without the details
- Repeat false ideas without making it clear they are false
- Be aggressive

("You're wrong!", "You're ignorant"). Instead, listen and ask questions that reveal why someone has those opinions ("What makes you think that?").

"Respect the fact that they may have had experiences that led them to believe what they believe," says Ecker.

The good news is that social events are excellent situations for refuting myths. Assuming there is at least some trust between you, the other person will probably hear you out, says Ecker. And corrections from credible, trusted sources are more effective. There's also far more time to discuss the topic in person than compared with, say, interactions on social media.

The bad news is that even with all this in mind, you are still unlikely to convince someone, especially if you are challenging their world view. "World view-dissonant corrections are by-and-large ineffective, especially in conservative people," says Ecker. "That doesn't mean that liberal people are immune to world-view effects, but I have only seen total lack of efficacy in conservative people."

So why even try? Firstly, people are much less likely to spread false information if they are held accountable for it, says Reifler. Questioning your relatives' false claims may make them think twice before spouting nonsense on another occasion.

And always consider the other people in the room.

"Even if you do not change your Aunt Susan's mind, you may sow a seed in your nieces' and nephews' minds," says Ecker.

Indeed, Cook thinks there is little chance of changing the minds of, say, the 7 per cent of people in the US who are very sure that global warming isn't happening at all. Instead, he thinks we should focus on the majority still open to persuasion. His studies show that people are less likely to fall for false arguments if they are "inoculated" against them.

For instance, forewarn them about the problem of false balance in the media – where commentators with no expertise are interviewed just to give an opposing position – and their views won't change when they read an article full of false-balance quotes. Those who are not warned become more doubtful.

So when you tell Aunt Susan that her incorrect views on climate science are the result of deliberate efforts to muddy

"Around 300,000 people died in South Africa because of denialism about HIV and AIDS"

the truth and thwart action, she might not believe you. But inoculating her children might stop them falling for climate change deniers' propaganda.

If all this seems discouraging, remember that the truth matters. Children are dying because of the false claims made about vaccines. It is estimated that 300,000 people died in South Africa because of denialism about HIV and AIDS.

And occasionally you might just change someone's mind – but don't expect any thanks. While Cook's father-in-law remains unconvinced about climate change, his father has changed his mind. But when Cook asked him why, he encountered a phenomenon seen in some studies: his father denied ever having thought otherwise. ■

COMMENT

Faith, hope and charity

UK regulations are cracking down on charities that promote bogus treatments. The rules should be applied strictly, says **Tom Chivers**

CHARITIES offering unproven or pseudoscientific treatments will face new regulations from the UK Charities Commission. Will this be enough to protect vulnerable people?

There is a special role in British society for charities, especially during the season of giving. You can donate to everything from school sports days to Siberian tigers, but to qualify for tax breaks, the recipients must show, with evidence, that there is a public benefit to what they do.

But, last year, I found that some charities offering complementary and alternative medicine seemed to be playing fast and loose with the words "evidence" and "benefit".

One large charity was offering to pay for autistic children to have pseudoscientific treatments to "cure" autism. Another was promoting similar treatments, including a bleach-like substance



called MMS. A third claimed that Wi-Fi made you ill. There is no good scientific evidence for any of these claims.

Last week, the UK Charities Commission announced that it will be stricter in its demands for evidence. Specifically, if a group claims that alternative treatments can reduce the symptoms of, or cure, a condition, it will have to support that claim with scientific, peer-reviewed evidence.

It doesn't mean that every charity will have to dig out a meta-analysis to prove that aromatherapy joss sticks smell nice, say. If a charity claims only to offer "relief and comfort", less stringent forms of evidence like personal testimony will do. But those claiming they can treat cancer will need to show that what they are doing actually works.

It all seems sensible, but how will the guidelines survive contact

JOSIE FORD

Wing and a prayer

How do we decide who to trust when human and AI disagree, asks **Peter Lemme**

ON 29 October, Lion Air flight JT 610 crashed into the sea off Jakarta with the loss of 189 lives. The investigation continues, but flight information recovered from the wreckage indicates that the pilots were battling with the autopilot. In a situation like that, who should we rely on: human or machine?

The automated system was supposed to correct the aircraft's pitch. Instead, it repeatedly pushed the nose down towards the ground. Thirteen minutes after take off, the plane was lost.

Every time something is added to make a plane safer, new ways are created to make it less safe. In 1988, the first commercial jets

arrived that made machines the leaders. The pilots can only operate within boundaries set by the machine. For the first time, pilots trusted the onboard artificial intelligence to stop them from doing something stupid.

Pilots can't know everything that is happening. To prevent them being overwhelmed with information, the data made available is only that which is deemed necessary to take the required action. Problems noted

"The data made available to the pilots is only that deemed necessary to take the required action"

by the aircraft that don't require pilot action are logged for the maintenance crew to read later.

Thus a pilot's awareness must stretch across multiple realities, in which the aeroplane behaves differently depending on its status. These realities are distinguished by all the combinations of failures that might be encountered.

Many of these combinations can never be fully anticipated, even by a machine intelligence. Humans are able to adapt to new realities better than any AI, especially because they hold human traits like sacrifice, trust, judgement and a disparate

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with reality? There are actually studies showing that homeopathic treatments work. It is just there are more and better studies showing they don't. How strict will the commission be?

The guideline tightening follows a review by the Good Thinking Society, a non-profit group that promotes rational thinking. It pointed out that the old guidelines were fairly solid, but often weren't being followed. The new guidelines look even better, says Michael Marshall at the society, but the proof of the pudding will be in how they are applied.

The regulation change is a small but significant victory in a war against quackery. Those who approach charities for medical help are often at their most vulnerable. Making it harder for unscrupulous or misguided groups to offer them snake oil can only be a good thing.

But if charities can get away with waving an underpowered study with no controls as scientific evidence, the new guidelines will have been a waste of time. It would be better for the commission to demand bodies show the preponderance of evidence supports their case. ■

Tom Chivers is a science writer based in London, UK

knowledge base to draw from.

There is no simple answer to whether humans or AIs should take the lead in cockpits. As a leader, the pilot questions the machine when it misbehaves. As a follower, the pilot questions themselves when the machine intervenes.

A machine is trustworthy only while everything in the plane is working optimally, and JT 610 had a record of maintenance issues.

Pilots must be ready and able to transition from follower to leader when the situation calls for it. ■

Peter Lemme is an aviation expert writing at satcom.guru

ANALYSIS Climate politics



SARAH SILBINGER / EYEVINE

A green deal that could save the planet

Chelsea Whyte

A PROPOSAL to eliminate US greenhouse gas emissions and create millions of jobs is garnering growing support, in part thanks to Alexandria Ocasio-Cortez (pictured above), a 29-year-old, progressive Congresswoman just voted into office.

Called the Green New Deal, its goals are wide-ranging. They include moving the US to 100 per cent clean and renewable electricity by 2035 and zero net emissions by 2050, while creating 10 million energy infrastructure jobs.

Tying climate change solutions to jobs is clever. It could follow the path to success of the Affordable Care Act (ACA), an Obama-era law that increased access to healthcare. Many people initially railed against the potential cost of that act, but the benefits were enjoyed widely and the backlash was swift when US Congress later attempted to reverse the law. The same may happen if climate change policy can provide secure, well-paid jobs. (As *New Scientist* went to press, the ACA faced fresh legal challenges.)

It might seem unfeasible to tackle such a large transformation in just 17

years, but that is because we are used to economic growth being inextricably linked to fossil fuels. In the early parts of this decade, there were signs this link had broken, but fresh emissions figures suggest we aren't there yet.

Decoupling economic growth from fossil fuels will require a massive expansion of renewable energy sources. Thankfully, these are getting cheaper every year. A 2017 report by the International Renewable Energy Agency says that by 2020, renewable power will, on average, be cheaper

"The goals of the Green New Deal include moving the US to 100 per cent renewable electricity by 2035"

than fossil fuels. In some cases, solar and wind will provide the lowest-cost electricity from any source.

With this in mind, Robert Pollin, an economist at the University of Massachusetts Amherst, estimates the Green New Deal would require a budget of about \$600 million per year.

That would fund retraining and paying workers, pensions for those in energy industries that must

shut down, and equipment to help communities that are dependent on fossil fuels to transition to renewable energy. The US government would need to institute clean-energy tax breaks, vehicle emissions standards and potentially a carbon tax.

A similar idea is being floated across the pond. Last week, a group led by French economist Thomas Piketty called for a new European body to fund research and development, and to aim to make industry greener.

Economically, these ideas could work. Politically, they are a harder sell. Proponents argue that the past few years have seen halting progress on climate change, so now is the time to stop taking the problem step by step and launch a climate-change moonshot to transform economies.

The trouble is, according to an analysis by the Carbon Brief news site, the clean electricity goal in the Green New Deal would only get the US halfway to the goal of limiting warming to 1.5°C by 2100. Achieving this goal could reduce devastating impacts on ecosystems and human health, says the Intergovernmental Panel on Climate Change.

So it isn't the whole answer, but it is at least the start of political leaders taking climate change seriously. Coupled with lowered consumption and changes in land use, plans like the Green New Deal could be the way we achieve a climate our grandchildren's grandchildren can live with. ■

APERTURE



There's the Earth comin' up. Wow, is that pretty!

IT CAME as no surprise since it was already in the mission plan, but the astonished cries of the astronauts were spontaneous. On 24 December 1968, Apollo 8 completed the first circumnavigation of the moon by humans. As it emerged from the dark side, Earth crept over the lunar horizon. It was the first time anybody had seen earthrise. Astronaut William Anders picked up his camera and took a photograph.

It is generally thought of as the first photograph of Earth taken from the moon, but it isn't. Moments before, Anders's commander, Frank Borman, had taken a black-and-white photo, and two years earlier, the Lunar Orbiter 1 probe sent back two blurry images.

But what is now known as *Earthrise* was in colour, the blue of our planet's oceans in clear contrast to the blackness of space and the barren, grey surface of the moon. When the film was returned to Earth and developed, it was a sensation.

"It has often been cited as the greatest environmental photograph ever taken," says Jennifer Levasseur, space history curator at the National Air and Space Museum in Washington DC. "And it kick-started what we call green politics today. What appeared so fragile from space engendered great empathy back on Earth. Its significance cannot be overstated."

In early 1969, the photograph was everywhere,

from newspaper colour supplements to TV news bulletins to T-shirts. Outgoing US president Lyndon B. Johnson sent all world leaders a copy as he left office, both as a political stunt, but also, says Levasseur, "to show them that this is all we have, war, disputes and politics notwithstanding".

Earthrise was chosen as the symbol for the first World Earth Day in April 1970, and its influence steadily grew. From politicians to flat-Earthers, *Earthrise* "was appropriated - or maybe misappropriated", says Levasseur.

It may be the most famous photograph ever. Levasseur thinks so, although she makes a case for a few others, including Alberto Korda's photo of Che Guevara. And there are many other images from Apollo missions, including Buzz Aldrin's footprint on the moon. Strikingly, the images all came from the same era, and yet, says Levasseur, as a statement of who we are and where we came from, it is *Earthrise* that still has resonance.

If it were taken today, would it have the same effect? She isn't sure. "Our expectations of technology are different now. Everybody 'knows' what Earth and even other planets look like from space, even if it's only in studio simulations."

In the end, though, that loss of awe is down to one man who picked up his camera on Christmas Eve 1968 and took a colour photo of our world from space, a first we are still talking about 50 years later. Mick O'Hare

Photographer

William Anders

NASA

The moment the Apollo 8 astronauts spotted Earth

William Anders: Oh my God, look at that picture over there! There's the Earth comin' up. Wow, is that pretty!

Frank Borman: Hey don't take that, it's not scheduled.

[shutter click]

Anders: You got a colour film, Jim? Hand me a roll of colour, quick, would you?

Jim Lovell: Oh man, that's great.

Anders: Hurry.

Lovell: Where is it?

Anders: Quick.

Lovell: Down here?

Anders: Just grab me a colour.

A colour exterior. Hurry up. Got one?

Lovell: Yeah, I'm looking' for one. C 368.

Anders: Anything. Quick.

Lovell: Here.

Anders: Well, I think we missed it.

Lovell: Hey, I got it right here [in the hatch window].

Anders: Let me get it out this one, it's a lot clearer.

Lovell: Bill, I got it framed, it's very clear right here!

[shutter click]

Lovell: Got it?

Anders: Yep.

Lovell: Take several, take several of

'em! Here, give it to me!

Anders: Wait a minute, just let me get the right setting here now, just calm down.

Lovell: Take...

Anders: Calm down, Lovell!

Lovell: Well, I got it right - aw, that's a beautiful shot... Two-fifty at f/11.

[shutter click]

Anders: OK.

Lovell: Now vary - vary the exposure a little bit.

Anders: I did, I took two of 'em here.

Lovell: You sure you got it now?

Anders: Yeah, we'll get - well, it'll come up again, I think.

COMING NEXT ISSUE...

NEW YEAR, NEW YOU

10 resolutions to make the most of 2019

Plus

LAND OF GIANTS

Black hole hunting in
the Atacama desert

GREEN SKY THINKING

A cleaner way to fly

BEYOND PLUTO

Our first glimpse of the
solar system's icy edge

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NewScientist

NEWS PREVIEW 2019

From electric cars and artificial blood to new triumphs in artificial intelligence and grim climate milestones, here's our pick of what to expect from the year ahead

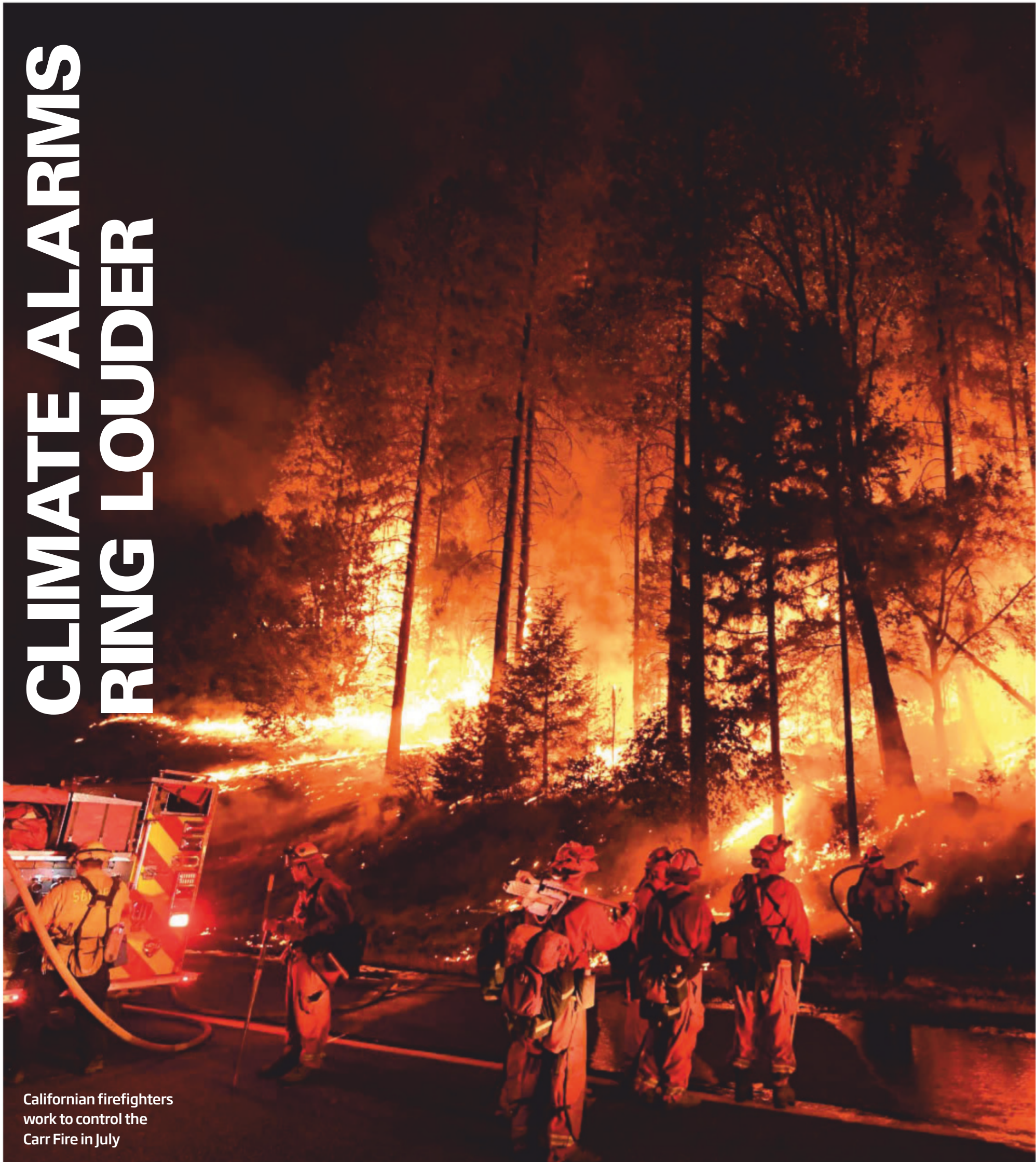


Hurricane Michael flattened homes in Florida in October. You can expect more events like this in the coming year

ANDREW CABALLERO-REYNOLDS/AFP/GETTY IMAGES

NEWS PREVIEW 2019

CLIMATE ALARMS RING LOUDER



Californian firefighters
work to control the
Carr Fire in July

MARK RALSTON/AFP/GETTY IMAGES

1

Early in the new year, if not sooner, the world will set a most unwelcome record. Global oil consumption will pass 100 million barrels per day for the first time – and keep climbing.

To have any chance of limiting warming to 1.5°C, greenhouse gas emissions need to start falling now, and fast, the latest UN climate report warned in October. But emissions are still increasing. They rose 3 per cent in 2018 and look set to keep rising in 2019.

Sure, the amount of renewable energy we produce is growing fast. But global demand for energy is growing faster. Just a quarter of the rise in energy demand in 2017 was met by renewables, according to the International Energy Agency, the body predicting the oil-consumption milestone.

In other words, renewables need to grow much faster just to halt the growth in fossil fuels, let alone displace them. Such a step change requires either a massive rise in investment in renewables, or the imposition of a high price on carbon to deter fossil fuel use. Neither is on the cards for 2019.

As emissions keep growing, carbon dioxide levels in the atmosphere will rise ever faster,

causing warming to accelerate. Unsurprisingly, 2019 is set to be one of the warmest years on record, perhaps even the warmest.

Whether this record is set will depend on the strength of the El Niño climate phenomenon that is forecast to develop in the next few months. This sees warm water spread across the surface of the Pacific Ocean, temporarily boosting global temperatures.

A strong El Niño made 2016 the warmest year on record; 2017 and 2018 were slightly cooler because there was no El Niño. However, the 2019 El Niño isn't forecast to be as strong or to last as long as the 2016 one, so the year ahead might not quite top the charts.

The coming year may also see atmospheric CO₂ levels hit a new milestone. The global annual mean level of CO₂ in 2018 is on track to be a little above 407 parts per million. In recent years, the level has been rising by 2 ppm in normal years and 3 ppm in El Niño years, when widespread droughts and wildfires increase CO₂ levels.

Depending on what a 2019 El Niño has in store, we could see the annual mean level in CO₂ approach or exceed 410 ppm.

Michael Le Page

"2019 is set to be one of the warmest years on record, perhaps even the warmest"

DNA ANALYSIS CRACKS COLD CASES

2

The net is closing on many criminals who have so far got away with it. Dozens of cold cases will be solved in 2019, as detectives tap DNA data used for tracing family trees.

The potential of this resource has only recently been discovered. In April, police in California arrested a new suspect in the case of the Golden State Killer, who raped and murdered people in the 1970s and 80s. They identified a man using a website called GEDmatch that helps people use DNA test results from services like 23andMe and AncestryDNA to trace their family tree. If someone has left DNA at a crime scene, the website can be used to identify family members of that person who have DNA online, and narrow the search.

This led to the arrest of Joseph James DeAngelo, and inspired Virginia-based Parabon NanoLabs to use the approach to identify 13 suspects in other crimes, leading to 11 arrests so far.

The company is now working on more than 100 cases, and expects to use the technique to solve at least 30 by the end of 2019. Another US-based team, Identifinders International, says it is working on a dozen murder cases.

Such investigations are only set to multiply. About 1 million people have uploaded DNA data to GEDmatch – enough to find third cousins for about 60 per cent of people in the US of European descent. About 1800 more add their DNA every day, so it won't be long before nearly every such person in the US is traceable.

And as users outside the US upload their DNA to GEDmatch, other countries will also be able to use it to solve crimes. Researchers at Stanford University in California recently developed a tool for linking genealogy sites with forensics databases, further strengthening the technique. By the time law-makers have decided how to regulate forensic genealogy and protect our genetic privacy, many more arrests will have been made worldwide. Alice Klein



NEWS PREVIEW 2019



Screening could lead
to fewer embryos with
inherited conditions

DR G. MOSCOSO/SCIENCE PHOTO LIBRARY

3

GENETIC DISORDERS PREVENTED

A marked fall in the number of babies born with inherited illnesses is possible, as a pre-pregnancy DNA test is used more widely.

The test checks whether prospective parents carry genes that, if both pass a copy to their child, will cause disease, known as a recessive condition. The test is usually only offered to people who know that recessive disorders such as cystic fibrosis run in their family.

But most carriers of these genes don't have any such warning, says Alison Archibald at Victorian Clinical Genetics Services in Australia. In 2019, the country will start a trial, offering free tests to 10,000 couples regardless of family history, screening for 500 illnesses. If it leads to fewer babies born with these diseases, it may be offered nationwide.

Since 2017, the American College of Obstetricians and Gynecologists has also recommended that all couples planning families have carrier tests for two of the most common recessive conditions: cystic fibrosis and spinal muscular atrophy.

In a study of 12,000 people in Australia, Archibald's team found that one in 20 people carried genes for cystic fibrosis or spinal muscular atrophy. Of these, one in 40 had a partner who was also a carrier, giving them a one in four chance of having an affected child.

Screening on a national scale could see rates of genetic conditions fall sharply. Couples who test positive may choose to undergo IVF, allowing them to select embryos that are free of the condition.

Couples are also increasingly opting for early fetal screening in pregnancy. Since 2011, an early-pregnancy blood test for Down's syndrome and other chromosomal disorders has been done by an estimated 10 million women worldwide.

There are concerns that more screening before birth will lead to discrimination against people with genetic conditions. But a study in Belgium found that 83 per cent of people with cystic fibrosis were in favour of pre-pregnancy screening. **Alice Klein**

"Screening on a national scale could see rates of cystic fibrosis and spinal muscular atrophy fall sharply"

ARTIFICIAL BLOOD TO THE RESCUE

Blood transfusions save lives, but supply doesn't always meet demand, which can lead to fatal consequences. Soon, we will be able to end that problem by making blood in the lab on demand, with no donors required.

Transfusions depend on armies of donors and complex networks for collecting and storing donated blood. Some countries are unable to build the infrastructure required to do this. Even in developed nations, hospitals can run short of supplies for people belonging to particular blood groups.

Such problems would be solved if we had a way to make effective artificial blood. One such type of lab-made blood will be tested

in people for the first time in 2019.

Blood has a lot of functions, but the most crucial is bringing oxygen to the tissues of the body. This job is done by red blood cells, which are packed with an oxygen-binding protein called haemoglobin. There have been several attempts to make artificial haemoglobin or to use animal versions of the protein, but these have hit problems, prompting researchers to try another angle: producing whole red blood cells instead.

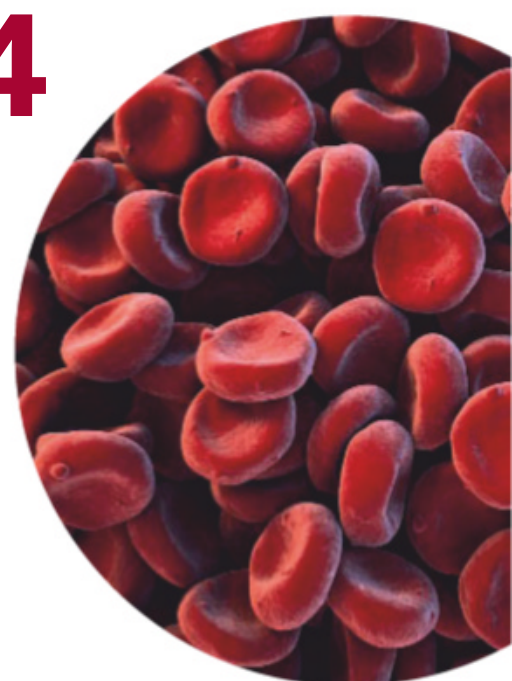
In the body, these cells are made by a kind of stem cell that normally lives in bone marrow. To make new red blood cells in the lab, Allison Blair at the University of Bristol, UK, and her

colleagues have extracted some of these stem cells and nurtured them so they multiply and start to produce functioning red blood cells.

Next year, 10 healthy volunteers will be injected with just a teaspoon each of fluid containing these cells. The cells will be labelled with a mildly radioactive tracer, to see how long they survive in the body compared with ordinary cells.

In a further advance, to cut out the need for a continual supply of stem cell donors, another team has developed a way to make these stem cells live forever in the lab. "That gives you almost a limitless supply," says Blair. **Clare Wilson**

4



NEWS PREVIEW 2019

"When will you build an electric car half as sexy as a Tesla?" That's what Germany's minister for economic affairs and energy asked the giants of his country's car industry at an event in November. And by calling out the heads of Volkswagen, Mercedes-Benz and BMW by name, there is no doubt Peter Altmaier was trying to embarrass them into action. He may not have long to wait.

Next year, electric cars from many mainstream manufacturers will hit the road. Some of them could even turn heads more than a Tesla.

Of course, Tesla's Model 3 gets a lot of the press. Tesla set out to make an electric vehicle that could compete in the luxury car market and its sales suggest it is succeeding. The car has been available in the US since 2017 and is due in Europe next February or March.

But if you are thinking of getting an electric car, Tesla is now just one of more than a dozen options. The Tesla 3 faces fierce competition from cars of all shapes and sizes,

including SUVs, sports cars and family saloons. And most of them will be from trusted manufacturers.

In 2019, we can expect the first electric cars from VW (Neo), Volvo (XC40) and Audi (e-tron). BMW is giving its i3 car a big battery upgrade that increases its range. Mercedes-Benz will ditch the Tesla components in its Generation EQ car in favour of homegrown technology. The BMW-made Mini E, first revealed in 2010, will finally graduate from concept car to practical whizz-around. And for people with deeper pockets, 2019 will also see electric vehicles from Aston Martin, Porsche and Jaguar.

With the European Union aiming to cut car emissions by 35 per cent in the next 20 years, widespread adoption of electric vehicles is needed. More choices from trusted car-makers will make this more likely. VW, for example, has said that it wants fully electric vehicles to make up 30 per cent of its new car sales. **Douglas Heaven**

5

HERE COME THE ELECTRIC CARS

A prototype Audi e-tron during testing in Namibia



“Enamel in teeth could help us identify mystery remains and put together a family tree for early humans”

TEETH SHED LIGHT ON EVOLUTION

6

Next year, we will start to learn what a host of ancient animal and early human remains really are, thanks to new techniques for identifying even fragmentary pieces.

Over the past decade, DNA analysis has overturned our ideas of human evolution. It has revealed that humans interbred with Neanderthals, and unveiled a hitherto-unknown group called Denisovans.

But it has limits. The DNA in remains doesn't survive long when conditions are hot or wet, so we won't get much from the tropics. Even in ideal conditions, DNA breaks down. The oldest DNA yet recovered comes from a horse that lived 700,000 years ago.

However, proteins can survive longer. One example is the collagen in bone, which can now be used to roughly identify organisms. The method is fast and cheap. Another technique is more precise. Enamel in teeth also contains proteins, which can reveal an animal's species.

In September this year, Enrico Cappellini at the Natural History Museum of Denmark used the method on remains of extinct rhinos and figured out how the species were related. This proof of concept was huge, because teeth are the most frequently preserved body part.

The technique should shed light on human evolution. “We have all these exciting fossils coming out of Africa, but we have no DNA to go along with them,” says Samantha Brown at the Max Planck Institute for the Science of Human History in Germany. Newly discovered species like *Homo naledi* and *Australopithecus sediba* cause confusion because we can't tell where they fit in our family tree. “Enamel could be useful for putting together those trees,” she says.

There is also the matter of finding a Denisovan skeleton. The species is known only from teeth and tiny bones, but a better specimen could already be in a museum - and enamel could unmask it. Michael Marshall



ABOVE: ROBERT CLARK/NATIONAL GEOGRAPHIC IMAGE COLLECTION; LEFT: AUDI AG

NEWS PREVIEW 2019

7

Gamers everywhere were watching as OpenAI, an artificial intelligence lab co-founded by Elon Musk, pitted a team of bots against some of the world's best *Dota 2* players at an annual tournament back in June.

Machines had been on a winning streak. In 2016, DeepMind's AI mastered Go. In 2017, a poker-playing bot called Libratus, developed by a team at Carnegie Mellon University in Pennsylvania, won a professional Heads-Up No-Limit Texas Hold 'Em tournament. *Dota 2*, a popular online battle game, looked to be next in line.

In the end, the bots beat amateur players and lost to pros – but that probably won't be the case next time. "I think OpenAI's chances are pretty high," says Julian Togelius at New York University.

In *Dota 2*, two teams of five vie for territory and resources across a fantasy-themed map, lobbing spells in a confusion of colour. The spectacle can feel like watching fireworks from a plane. Yet behind the fast-paced action,

players make constant trade-offs between short-term advantage and the long game. This makes it hard for computers to master.

After playing thousands of years' worth of the game, OpenAI's bots managed to beat a team of amateurs, largely by dominating skirmishes. The bots have a reaction time of 0.2 seconds – roughly that of humans – but in that instant they can take in the entire state of the game, including details that human players have to click on or switch screens to read.

This makes the bots formidable in battle because they know the exact effect of any action at all times. The bots are also ruthless. Human players often get killed trying to save their buddies. Bots aren't so stupid.

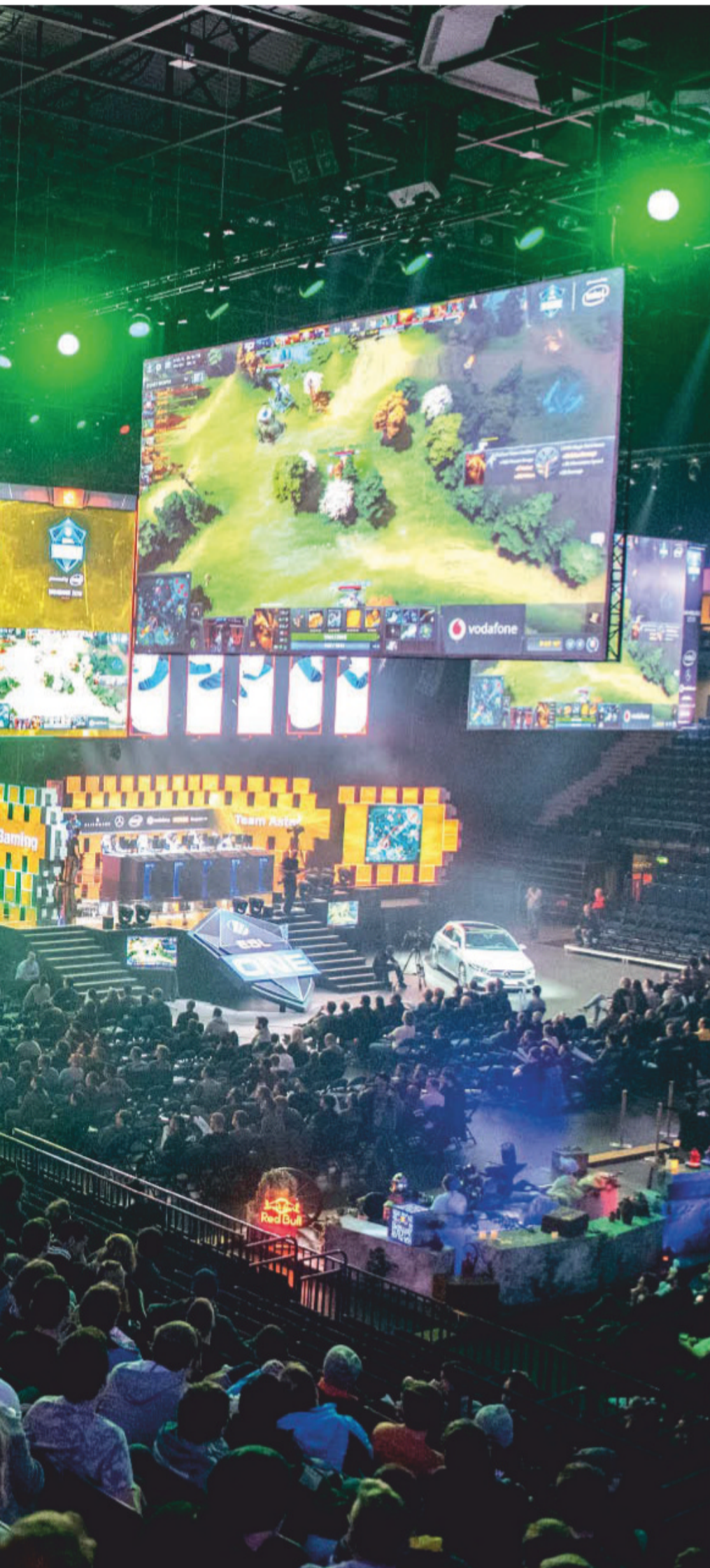
Even so, the pro players at June's contest beat the bots by outplanning them. But better planning is something OpenAI has said it will be focusing on. With another 12 months of training under their virtual belts, the bots look to be where the smart money will head at 2019's tournament. **Douglas Heaven**

AI BEATS THE BEST AT BIG BATTLE GAMES



DPA PICTURE ALLIANCE/ALAMY STOCK PHOTO

Dota 2 teams compete
at ESL One Hamburg,
Germany, in October



"The bots are also ruthless. Human players often get killed trying to save their buddies. Bots aren't so stupid"

SEEING A BLACK HOLE FOR REAL

8

It is time to stare into the abyss. The Event Horizon Telescope (EHT) has already made its first observations of the supermassive black hole at the centre of our galaxy, and the results - maybe even the first ever picture of a black hole - are expected next year.

Nine radio observatories around the world, including four in the US and one in Antarctica, make up the EHT. They all turn on simultaneously, combining to make a single, powerful "virtual telescope" spanning the planet.

In April 2017, the EHT looked at two supermassive black holes: Sagittarius A*, at the centre of the Milky Way and the closest one to us; and the much more massive black hole at the centre of nearby galaxy M87.

The EHT collaboration's images will look not like a sphere of darkness, but rather a banana of light. As the black hole rotates, it actually drags light along with it. This causes a bright crescent to appear on the side rotating towards us, juxtaposed with a dark shadow from the event horizon - the edge of the black hole itself.

The images will be the first ever ones of an event horizon, and the first direct proof that such a horizon exists, says collaboration member Heino Falcke at Radboud University Nijmegen in the Netherlands. We have hints from gravitational wave data (see "LIGO to spy more space oddities", page 39), but "you can have something that almost quacks like a duck, but it is a pigeon in disguise", he says. "All of the evidence is indirect, and seeing is believing."

The observations could also help solve one of the greatest mysteries in modern physics: the fact that gravity, which acts mostly on very large scales, doesn't seem to play well with quantum mechanics, which acts over small scales.

"By seeing this event horizon, that abstract problem becomes a physical, real problem in the real universe: you can point to a point in the sky and say, 'that's where it goes wrong'," Falcke says. Leah Crane

NEWS PREVIEW 2019



Black hole mergers
are a major source of
gravitational waves

MARK GARLICK/SCIENCE PHOTO LIBRARY/GETTY

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LIGO SPIES MORE SPACE ODDITIES

The hunt for gravitational waves is back on. After a little over a year of upgrades, the Laser Interferometer Gravitational-Wave Observatory (LIGO) is preparing for its third run of observations.

Gravitational waves are ripples in space-time that emanate from massive objects as they move, and that stretch and squeeze everything in their path. LIGO detects them using powerful lasers shot onto mirrors and sent through long tunnels. So far, it has spotted the signals resulting from 10 pairs of black holes merging and one pair of neutron stars smashing together.

During its year off, LIGO was upgraded with new mirrors, panels to control any stray light that might leak into the detector and new amplifiers to make the lasers even more powerful. These updates should extend LIGO's reach into the cosmos from about 326 million light years to about 391 million.

We should also have more detectors than

before. LIGO itself consists of a pair, one in Hanford, Washington state, and one in Livingston, Louisiana. There is also a third, the Virgo detector in Italy. Researchers hope a fourth will be up and running in Japan by the end of the new observation period. Each addition helps pin down the origins of a signal so we know where to point telescopes for follow-up observations.

Gravitational wave hunters are excited at the prospect of spotting something new with their upgraded systems. Joseph Giaime, the head of LIGO Livingston, hopes to see a black hole and a neutron star merge, rather than two objects of the same sort. "It should be quite a show as the neutron star gets torn apart," he says.

The upgraded detectors are set to turn on around February 2019 and continue running for a full year. If all goes to plan, we should see a new gravitational wave event at least every couple of weeks. **Leah Crane**

"One gravitational wave hunter hopes to see a black hole and neutron star merge. It should be quite a show"

GOODBYE, GLUTEN-FREE

Bread and pasta may be back on the menu for people with coeliac disease participating in a clinical trial next year.

Coeliac disease makes you unable to eat foods containing gluten without experiencing an immune reaction that damages your gut and can cause vomiting, diarrhoea and fatigue.

A vaccine called Nexvax2 could change that. It contains synthetic fragments of gluten that can be recognised by the immune system, but don't trigger a full immune reaction when introduced in gradually increasing doses. This teaches a person's immune

system to see gluten as harmless.

The vaccine has performed well in five small clinical studies. In one of these, eight people with coeliac disease given the vaccine were each able to eat nine gluten-containing cookies over three days without feeling sick or showing signs of inflammation in blood tests.

A larger trial of the vaccine in 146 people with coeliac disease is now under way and due to finish at the end of 2019.

Half of the participants will be injected with progressively stronger doses of the vaccine twice a week, for 16 weeks. The other half will get placebo injections instead.

The efficacy of the vaccine will be assessed by giving all participants a smoothie to drink containing as much gluten as in two pieces of bread. Each person's symptoms and inflammatory blood markers will then be monitored.

Based on the results of earlier trials, Ken Truitt at ImmusanT, the US company developing the vaccine, is optimistic it will work. It could change the lives of the 1 per cent of people who have coeliac disease and currently have to remain vigilant for all sources of gluten, like wheat, barley and rye, he says.

"Our ultimate goal is to let people with coeliac disease eat an unrestricted diet," he says. **Alice Klein**

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NEWS REVIEW 2018

From advances in mind reading and cutting-edge medical procedures, to AI law enforcement and a CRISPR controversy, 2018 was a year of many highs and lows. Here are our top picks of the year

JANUARY

Airborne fire starters? At the beginning of the year, we broke the news of the first documented evidence that falcons and kites seem to deliberately spread wildfires. Eyewitness accounts in Australia suggest they drop burning twigs into new areas to flush out prey. Birds may exhibit similar behaviour in Africa, the Americas and South Asia.



APRIL

Humans are beginning to meld with machines. In April, came news of a mind-reading headset that lets you query Google with just a thought. It works by reading signals sent from your brain to your jaw as you think, even if you don't speak. The story came hot on the heels of two AI systems capable of guessing what you are looking at by scanning your brain.

MAY

Following the revelation that Cambridge Analytica had access to millions of Facebook users' data, a *New Scientist* investigation discovered that researchers at the University of Cambridge had left similar data from a personality quiz app online for anyone to access.

JUNE

The great ape family welcomed a new member. We revealed that a comparison of genomes found signs of a previously unknown species of chimpanzee that once lived in central Africa. As far as we know, there are no physical remains of the ancient ape, but DNA analysis suggests that it mated with bonobos 400,000 years ago and that some of its genes persist in apes living today.

SEPTEMBER

The normally sedate world of mathematics was rocked by claims of a solution to one of the field's longest-standing problems. Michael Atiyah, one of the most eminent mathematicians in the UK, revealed his solution to the Riemann hypothesis, a 160-year-old puzzle concerning the nature of prime numbers. His peers were unconvinced, and the consensus is that the problem remains unsolved.



OLUSCARFF/GETTY

OCTOBER

Governments around the world increasingly rolled out artificial intelligence in 2018. In this month, we revealed that Hungary, Latvia and Greece were testing an automated lie-detection system at four border crossings. This used AI to quiz travellers and analyse video of their faces to look for gestures associated with lying. AI experts said such systems are too inaccurate for real-world use.

A GOOD YEAR FOR:

AI DOUBLE ACTS

The best AIs this year were partnerships. Generative adversarial networks consist of one system inventing things and the other checking if they pass muster. In 2018, they came up with sonnets, pranks, fashion items and more.



OTHMAN SBAI, MOHAMED ELHOSEINY, ANTOINE BORDES, YANN LECUN AND CAMILLE COUPRIE

MOON FANS

Twitter exploded when we reported it was possible for moons to have moons, known as moonmoons. This year, we also learned that Earth may have a pair of "ghost moons" made from dust, and China launched a mission to the far side of the actual moon.

SILKWORMS

What a year to be a silkworm. In 2018, genetically modified silkworms made a completely new kind of silk never seen in nature before, while CRISPR enabled other silkworms to resist a lethal virus.

DRY JANUARY

A study of 141 drinkers found that giving up alcohol for a month can lower blood pressure, cholesterol and the levels of cancer-related proteins in the blood. The work behind this study began with a small 2013 experiment involving *New Scientist* staff.



AUSCAPE INTERNATIONAL PTY LTD/ALAMY

FEBRUARY

This month, we revealed that five children born with underdeveloped ears had been given new ones made from their own cells. The technique involved was similar to the one used in the 1990s to create the "Vacanti mouse", which had a human-like ear growing on its back.

MARCH

It took over a decade to fully sequence the first human genome, but in March we reported that a team at London's Great Ormond Street Hospital for Children had used rapid sequencing to diagnose rare disorders in 10 critically ill children. This led to improved treatment and protected some of them from life-threatening complications.

JULY

You might think you read a story about the nature of time in July, but that is only because you can't think in quantum physics. The mind-bending thought experiment in question indicates that our perception of time may come from our inability to process information in a quantum way. Computers built on the principles of quantum mechanics might avoid this disadvantage, the researchers found.

Our ability to perceive time may actually result from a quantum failing



AUGUST

A sliver of bone from a cave in Russia became the biggest archaeological story of the year, when researchers published their finding that it came from an ancient teenager who had a Neanderthal mum and a Denisovan dad. "Denny" is the only first-generation hybrid hominin ever found. Back in March, it was revealed that Denisovans also mated with our own species on at least two occasions.

NOVEMBER

He Jiankui shocked the world when he announced the birth of the first ever gene-edited babies. The CRISPR technique was used to disable a gene to create children who are resistant to HIV, He said. So far, the trial has produced a pair of twin girls. The experiment was widely condemned by geneticists at a summit on gene editing held in Hong Kong the same month.

DECEMBER

As the year drew to a close, *New Scientist* revealed that UK police are turning to artificial intelligence in a bid to stop violent crime. The system, currently being trialled by nine police forces, attempts to predict the risk of someone committing or falling victim to gun or knife crime. A report from data science organisation the Alan Turing Institute warned that the scheme had "serious ethical issues".

A BAD YEAR FOR:

BELIEVING WHAT YOU SEE

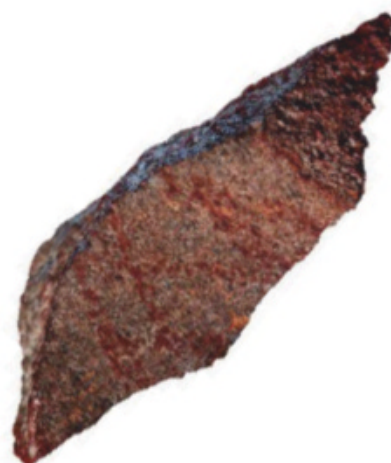
It is only a matter of time before an AI-powered fake video sparks a political crisis. So-called deepfakes leapt ahead in quality this year, making it even easier to fool people. Academics are now betting on when the first fake video scandal will occur.

GETTING ALONG IN SPACE

Tensions ran high in orbit, as a hole in a craft attached to the International Space Station sparked accusations of sabotage between Russia and the US. It didn't help that the US also pushed ahead with plans for a new military branch, the Space Force.

BORING OLD COMPUTERS

Last year, we predicted that 2018 would see the first quantum computer capable of outperforming regular machines. That didn't quite happen, but quantum computers are improving fast, with Google announcing its largest quantum chip yet.



MODERN ART

New is out, old is in. This year we learned that the world's first drawing was a red crayon doodle (pictured, left) made 73,000 years ago. And the earliest figurative art was also announced, a 40,000-year-old drawing of an unknown animal.

CRAIG FOSTER

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INGO OELAND / ALAMY STOCK PHOTO

Silly season

Discover how wombats can poop cubes in our 35-page festive special. Also featuring penguin archaeology, death rays, the science of the perfect cocktail, cave bears of very little brain, fungi economists and a whole multiverse more...



The best of all possible worlds

Is quantum theory the easiest route to improving your life? Probably not, says Philip Ball

MINCE pie or another slice of Christmas cake? If you're having trouble deciding, perhaps you need the Universe Splitter. Type the choices confronting you into this handy app and it promises to contact "a laboratory in Geneva" that will conduct an experiment to tell you which decision to make.

The app's guarantee is that, whatever the best choice might be, you will get to enjoy it for sure – if not in this world, then as another you in a parallel one. Sink back into your armchair, pour a brandy (or sherry?) and prepare to have your mind split apart. We are about to enter the quantum realm – home, perhaps, to many worlds where you can have your cake, and pie, and eat both. Or can you?

The origins of this agreeable suggestion lie in a city famed for its sweetmeats: Vienna, Austria. In the early 1920s, physicist Erwin Schrödinger was seeking an equation that could explain the workings of quantum particles – things like photons and the tiniest building blocks of the matter that makes up you, me, your armchair and that plate of Christmas cake.

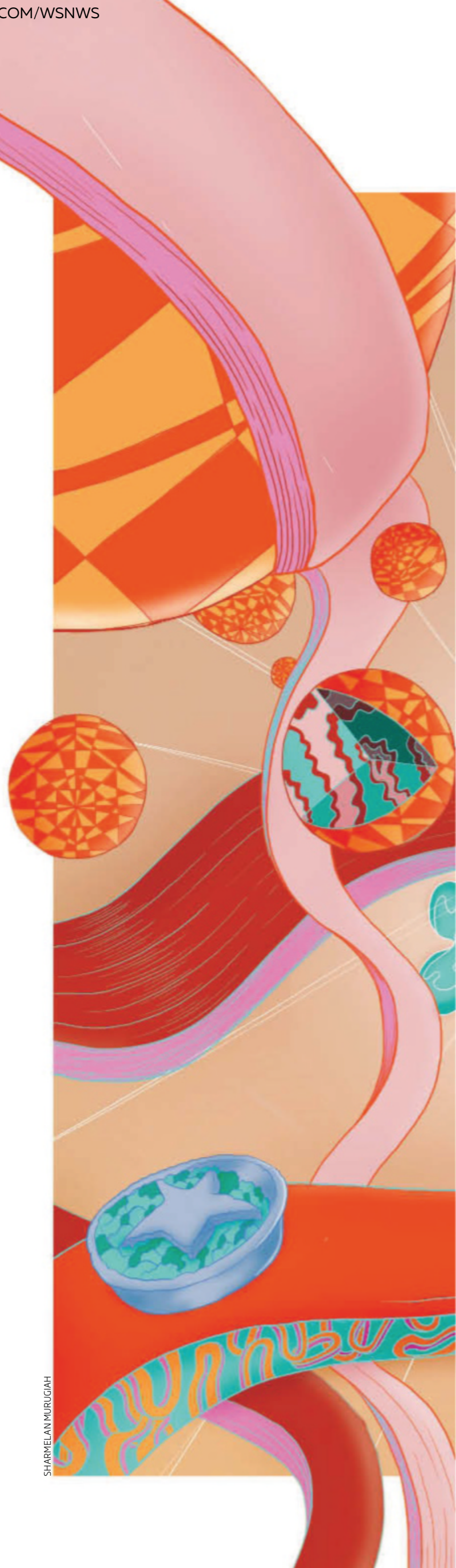
In 1925, Schrödinger found his equation, which indicated that everything there is to know about a quantum particle was described by a rather mysterious mathematical entity

called a wave function. A year later, German physicist Max Born argued that this wave function supplied you with the probability of finding a quantum particle at a point in space, if you performed some experiment to measure it. As long as you didn't measure it, this position was somehow indefinable, characterised only by this spread-out probability wave.

This was odd. The quantities in the equations of classical physics represent measurable properties of the world – the charge of an electron, the location of a brandy glass, the mass of a mince pie. Properties, not just probabilities; the thing itself, not our experience of it when we seek to observe it. Born's interpretation seemed to imply that, until we measure a quantum particle, "collapsing" its wave function into a certain and unique outcome, we can't really speak about it at all.

This raises all sorts of hairy questions. For a start, what counts as a measurement that takes us from probability to certainty? Quantum experiments have shown that it seems to involve not just doing something with a measuring

"The Universe Splitter app contacts a lab in Geneva to make your decision"



SHARMELAN MURUGIAH



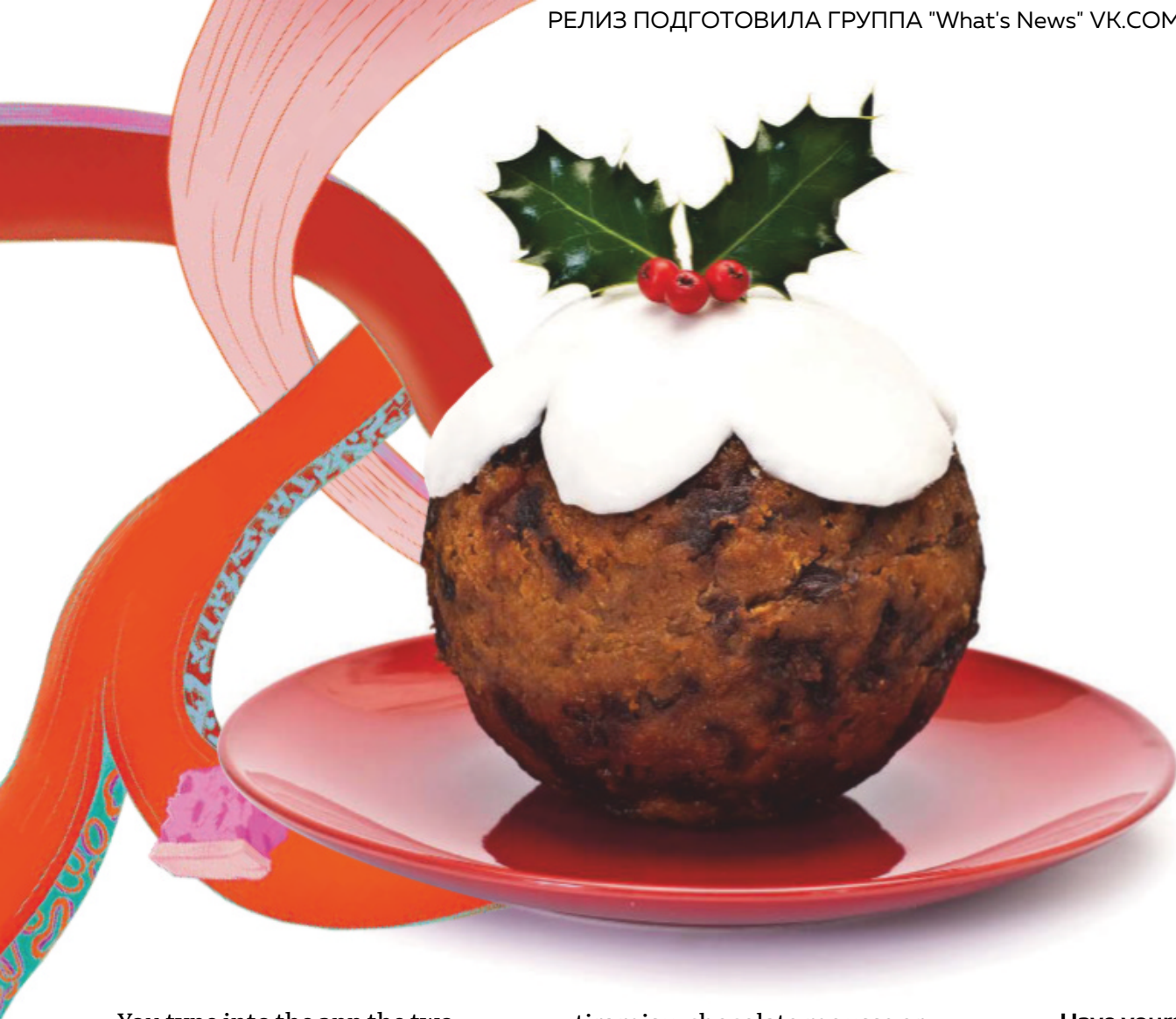
instrument, but also consciously noticing the result. So what is “real” before we look? And what happens to other possible outcomes encoded in the wave function when we force it to collapse into just one?

Multiplying yous

The Universe Splitter emerges from one attempt to solve these puzzles. In the cold war US of the 1950s, a PhD student at Princeton University named Hugh Everett III produced perhaps the most mind-boggling doctoral thesis of all time. He proposed that Schrödinger’s wave function doesn’t collapse at all, and the other possibilities encoded in it don’t actually disappear when we make a quantum measurement. Instead, every time anyone makes a measurement, the universe splits into a number of universes equivalent to the number of possible outcomes – along with a copy of whoever is doing the measuring, and everything else in that universe, too.

Multiplying universes and selves in this way might sound implausible, not to mention highly profligate. But that’s an aesthetic, not a scientific objection, and for adherents of the “many-worlds” interpretation of the quantum realm, this is serious science. David Deutsch at the University of Oxford, one of its most committed advocates, once began a talk at a meeting honouring Everett’s work by saying, “I’ll start with a simple fact: in this room, in some nearby universes, Hugh Everett is here with us, celebrating.” Everett had in fact died several years earlier, in 1982 at the age of just 51, his end hastened by excessive eating, heavy drinking and chain smoking – at least in the branch of the quantum multiverse where we all ended up.

This many-worlds interpretation implies that if we attach our fates – cake or pie? – in the macroscopic classical world to the outcome of a universe-splitting quantum measurement in the quantum world, we can ensure all outcomes occur somewhere in the quantum multiverse. This means we enjoy the best (and also the worst) of all possible worlds, whatever choice we make. Which is what the Universe Splitter app purports to do. ➤



You type into the app the two possible outcomes of the decision you have to make, and press the button. According to the blurb from its Californian maker, Aerfish, it connects “to a quantum device, which fires single photons at a partially-silvered mirror. Each photon will simultaneously bounce off the mirror and pass through it – but in separate universes”.

The device will inform you which outcome was measured in the world you entered and the associated decision. But because the universe has just split, it will be telling you the opposite in a parallel world. Follow through with the decision it gives you, and you can rest assured you are also experiencing the other elsewhere.

Physicist Lev Vaidman at Tel Aviv University in Israel is unequivocal that this sort of self-splitting really occurs. “Based on what I know from physics, this is the only reasonable option,” he says. “At the present moment, there are many different Levs in different worlds.” He says his “I” corresponds not just to a particular Lev in the moment, but also to many Levs in the future.

In fact, Vaidman merrily creates his own Levs using his own free Many Worlds app – the Universe Splitter will set you back \$1.99 – which also uses a quantum optical measurement to make a decision with up to six outcomes for you. You may need to choose between eating strudel,

tiramisu, chocolate mousse or cheesecake, he suggests. If you “have a strong will and fulfil what the device tells you, your parallel selves will fulfil the other options”. Delicious.

But before you tuck in, there’s a problem. If, in the many worlds, every possible outcome of a quantum measurement happens with 100 per cent certainty, then what are those probabilities encoded in Schrödinger’s wave function all about? This is the biggest stumbling block for Everett’s idea: explaining why quantum mechanics looks to be governed by probability, if it is actually fully deterministic because everything that can happen does.

In the late 1990s, Deutsch offered an explanation. Imagine you fancy Christmas cake rather more than the mince pie, but still hanker after both. You could set up a quantum decider experiment to reflect your leanings – in the normal quantum formulation involving probabilities, with say 90 per cent chance of the “cake” outcome, and 10 per cent “mince pie”.

In the many-worlds formulation, you say that both branches are reached with 100 per cent probability, with what used to be probabilities becoming

Have yourself a very quantum Christmas

“branch weights”: essentially, how biased you have made the experiment towards or against a particular outcome. Deutsch showed that, if you know that each of your split selves will experience only one universe after the event, the only rational thing to do is to treat these branch weights as if they really are probabilities in the pre-split universe. “If Everett’s view is true, branch weight is an objective physical quantity with the right formal properties to be probability,” says David Wallace at the University of Southern California.

Not everyone is convinced. For one thing, this take seems to depend on saying that the apparent probabilities are nothing more than how we, if we are rational about it, ought to regard branch weights. An explanation that demands we assume a certain attitude towards the world doesn’t seem particularly compelling.

Vaidman advocates a different tack to overcome the many-worlds probability problem. His explanation is known as “self-locating uncertainty”. He illustrates it with a thought experiment. Imagine you agree to take a pill that puts you to sleep, and are placed in a room containing a chest. You know that, while you are asleep, someone else will perform a quantum experiment – fire a photon at a half-silvered mirror, say – and, according to the outcome, either place \$1 million in the chest or nothing at all. In this scenario, when you wake up, it is perfectly reasonable for you to say before you look that there is a 50 per cent chance of the chest containing the fortune or not – a subjective probability that is set to be equal to the objective branching weight in the quantum experiment. In this scenario, apparent probability comes from the way that, after a quantum splitting, we are unsure which branch of the quantum multiverse we have ended up on.

Mateus Araújo at the University of Cologne, Germany, is unsure this solves the problem, either. “Usually we talk about the probabilities of a future experiment, not one that has already been made,” he says. “If we’re thinking about probabilities of future outcomes, the question of which branch I will end up on doesn’t even

Continued on page 47 ➤

“You have split innumerable times in reading this article – faster than thought itself”



make sense, because the notion of 'I' changes. You know that there will be future versions of you in all branches, all of which see a single outcome and remember being you now. There is no uncertainty."

Behind all this talk about what probability means in the many-worlds interpretation lurks a more fundamental question: what does "I" mean when worlds divide? Any quantum interaction, anywhere in the universe, that ends up with a classical outcome – a protein channel in a brain cell contributing to a thought that becomes an action, for example – should split the universe. It follows that I have split countless times while writing this article, as you have while reading it – faster, indeed, than thought itself. There's never a moment when you can be aware of a unique you.

Who exactly are you?

So in that sleeping-pill thought experiment, is the "I" that goes to sleep the same as the I that wakes up? If we are not defined by a unique thread of conscious awareness, how exactly are we defined? Many-worlders deny that identity is a problem, saying that the "I" is just a well-defined point in – or perhaps trajectory through – the branching multiverse. But it isn't easy to see what that means, if the branching is more fine-grained than thought.

Besides, the implication of an app like the Universe Splitter seems to be that, ultimately, our intentional acts can split the universe. The experiment is just the tool we do it with. But wasn't many worlds supposed to do away with the observer's apparent ability to shape reality in the conventional view of quantum mechanics?

We haven't heard the last word yet – probably. And if you are still having difficulty deciding between Christmas cake and mince pie, bear in mind one caveat mentioned on the Universe Splitter website, should you choose to use it. You won't be able to chase your other selves down their paths through the multiverse. "Universes cannot contact one another." ■

Philip Ball is half the man he used to be

Boogie on!

The benefits of dancing go far beyond having a good time, finds Stephanie Kramer

NOT all of us have what it takes to be a dancing queen. But whether you are a politician with two left feet or a *Strictly Come Dancing* wannabe, if you like to dance you are in luck. Ballet, ballroom or breakdancing, it doesn't matter: getting into the groove does wonders for you. And it's not just the joy of moving to music. Dancing is good for the brain too. It can change the way you think and even keep your mind sharp as you age.

"People are born to move. They are born to move rhythmically," says dance psychologist Peter Lovatt at the University of Hertfordshire, UK. Admittedly, we are not all blessed with the same degree of talent for it, but dancing is ingrained in human nature. People across almost all cultures have done it for as long as we know. Indeed, a sense of rhythm seems to be innate. Telltale brain activity in newborn babies reveals that even they can

spot when a drummer skips a beat.

Humans are not the only species with rhythm. The list is not long, but other groovers include elephants, sea lions and bonobos. One thing most of them have in common is a complex social life, leading to the idea that a sense of rhythm might have evolved as part of a group's need to coordinate its actions. Indeed, studies reveal that when people move in synchrony they experience a stronger sense of community and are more altruistic towards one another. Likewise, children who dance together turn out to be more cooperative in subsequent games. What's more, when professional dancers watch clips of dancing their brainwaves begin to synchronise. "Moving together in rhythm supports social bonding," says Lovatt. "It increases prosocial behaviour."

What is now emerging is that dancing also has remarkable benefits ►

Emma Stone and Ryan Gosling get in sync in *La La Land*



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AFP/GETTY

**Born to dance:
Ginger Rogers
and Fred Astaire**

for individuals. For a start, it can improve thinking skills. In one study, college students either danced, cycled, listened quietly to music or sat still, and did tests of mood and creativity before and after. Those who got up and danced showed increases in creative thinking after just 5 minutes of moving to music, and their mood improved too.

The two things are probably connected. Dancing releases feel-good neurochemicals into the bloodstream called endorphins, which relieve anxiety and depression. "You get an increase in mood when you dance and you also get an increase in creative problem-solving," says Lovatt.

"Mood has an important role in cognition," agrees Joe Verghese at the Albert Einstein College of Medicine in New York. But there's far more to dancing than that. The reason it has an edge over other types of exercise may stem from it encompassing so many elements: emotional, cognitive, physical and social. "Dance is a complex activity," says Verghese.

Less surprisingly, it can also boost coordination, spatial navigation and

memory – particularly if you are trying to master a new step or routine. "There are multiple effects on the brain," says Verghese. Among other things, dancing engages cognitive and sensorimotor regions involved in planning and performing movement. It literally alters the connections between neurons and how they communicate.

"Dance affects some parts of the brain more than others," says Verghese. One key region is the hippocampus, a pair of structures deep inside that are involved in learning, spatial awareness and long-term memory. As we age, the hippocampus normally loses about 2 or 3 per cent of its volume every decade. After age 70, that increases to as much as 1 per cent each year. And the loss is particularly rapid in people who have dementias such as Alzheimer's disease. Intriguingly, however, the

"Your mood improves when you dance – and so does your problem solving"

hippocampus can grow in response to various mental and physical challenges, including dancing.

A study published last year compared healthy adults aged 63 and older who either danced or took part in aerobics classes twice a week for six months and then weekly for a year. MRI scans showed an increase in the volume of the hippocampus in both groups. In the dancers, this appeared to be linked with improved balance. Another recent study found that dancing can reduce the loss of white matter in the brain, which also tends to accelerate with age. White matter tracts are like highways between brain areas and are involved in emotional processing, focus and problem-solving. When the researchers compared people who either walked, stretched or danced three days a week for six months, they found that only the dancers showed a slowdown in white matter loss.

These findings fit with research by Verghese into which leisure activities might reduce dementia risk. His team followed 469 people older than 75 for an average of five years and found that those who enjoyed cerebral hobbies such as reading and doing crossword puzzles were less likely to develop dementia. Dancing was the only physical activity with a similar effect – in fact, people who danced had the smallest cognitive decline of all.

Verghese hopes that more research will help quantify the effectiveness of dance and identify how it can best be used to improve brain health. He is now conducting a pilot study with 32 adults aged 65 and older, who for six months will participate in either social dancing (for example, foxtrot, waltz and Latin) or treadmill-walking. At the end, brain scans will reveal where any changes have occurred.

All this is very good news. If you have ever wanted to learn to tango or were simply too embarrassed to share your dad-dancing moves, here is your excuse to get on the dance floor and strut your stuff. It doesn't matter when in life you take it up, any time is the right time to dance. ■

Stephanie Kramer's motto is "Why walk when you can dance?"

Rogue traders

We thought economics was a uniquely human pursuit. But even simple organisms are at it, says Daniel Cossins

“THE propensity to truck, barter and exchange one thing for another... is common to all men, and to be found in no other race of animals,” wrote Adam Smith in *The Wealth of Nations*. That was back in 1776, but the idea that humans are the only species capable of economic behaviour persisted for a long time. Intuitively, it makes sense. Responding to shifts in supply and demand, for instance, must be the preserve of species with brains hefty enough to think through decisions rationally.

Or so we thought. As we get to know Earth’s myriad other species better, it is becoming apparent that many animals and organisms make trades, and that some are surprisingly savvy wheeler-dealers capable of manipulating the market in their own selfish interests. From frisky baboons to fish offering spa treatments on the reef, pretty much everywhere we look in nature we find evidence of surprisingly sophisticated economic decision-making. Even fungi are at it, and according to the latest studies, these brainless soil dwellers give the impression of being more rational than us.

Such revelations are handing us a fresh understanding of the origins of cooperation. They also chip away at the idea that sophisticated behaviour requires a big brain. They might even teach us a thing or two about ourselves, says Toby Kiers, an evolutionary biologist at the Free University Amsterdam. “What are the basic strategies organisms have evolved to



MEDIA DRUM WORLD/ALAMY

cope with relentless variation in resource availability? It is naive to think an MBA will teach us everything we need to know.”

Anyone who has watched a wildlife documentary knows that cooperation is common in nature. Monkeys groom one another, hyenas hunt in packs. And it is not just animals of the same species that work together. Until recently, all this collaboration didn’t make much sense in the context of Darwin’s theory of evolution by natural selection. If ruthless self-interest is the rule, why cooperate?

When Ronald Noë began watching

baboons in Kenya in the early 1980s, there were two answers to that question, both with flaws. The first was “kin selection”, the idea that an animal sometimes stands a better chance of passing on its DNA not by finding a mate itself but by helping a close relative to reproduce. But kin selection can’t easily account for cases in which unrelated species help each other.

The other argument was “reciprocal altruism”, which says that animals that help others do so because they know they will get something in return. Game theory was invoked to explain how an altruistic animal could guarantee reciprocity, with evolutionary theorists using a two-player game called the prisoner’s dilemma to figure out how it worked in nature. But there was a problem. “They were building card-houses of one model on top of another and never bothering about empirical evidence,” says Noë, who recently retired from the University of Strasbourg, France.

Out in the field, he quickly noticed their error. When two low-ranking baboons teamed up to challenge the dominant male so that one of them could mate with a female, they didn’t always stick with the same collaborator after the dethroning, as the theorists had assumed in their models. Quite the opposite. “These males switched partners and played their friends off against each other” to make sure they got more mating time than their collaborators, says Noë. Big baboons like Stu, the first challenger that Noë studied, knew that a collaborator

Clean your scales, guv’nor? Cleaner wrasse operate according to savvy economic principles

would accept less rather than risk losing his support.

"In a nutshell, this showed that the essence of cooperative relationships was partner choice," says Noë. In baboon society at least, when it comes to the exchange of services in pursuit of mating, the fact that individuals like Stu could shop around for the best deal from prospective collaborators makes all the difference. "Partner choice is what drives the market," says Noë.

In 1994, together with Peter Hammerstein, now at Humboldt University in Berlin, Noë set out his theory of biological markets, inspired by his observations of baboons. Then he tried applying it to all manner of other species to see if it would explain their cooperative behaviour. It worked. And although it didn't catch on immediately, the new theory captured the imagination of several young biologists, including Redouan Bshary, then one of Noë's PhD students.

Fishy business

At that point it had only been applied to animal behaviour already recorded in the literature. "I thought it would be nice to go out and explicitly test it in the wild in a new system," says Bshary, who is now at the University of Neuchâtel in Switzerland.

Bshary settled on a diminutive reef fish called the cleaner wrasse, which scrapes a living nibbling tiny parasites from between the scales of other fish that pass its cleaning station. He picked this wrasse because even though its behaviour is a nice example of mutualism, in that the cleaners get food and the clients get cleaned, there is a conflict of interest. The cleaners like to take nips of their client's protective mucus layers more than they do the parasites, so they are liable to cheat. "That means [to get good service] clients have to get cleaners to go against their preference, and cleaners have to choose when to cheat," says Bshary.

Having learned to scuba-diving, Bshary spent countless hours observing cleaner wrasse in the Red Sea. He saw that they have two types of client. There are "visitors", such as parrotfish, which can grow 40 cm long and can travel easily between several

cleaning stations. And there are "residents", like the smaller melanurus wrasse, that tends to stick to one. Bshary figured that visitors had a strategic advantage because they could shop around. Sure enough, in 2002, he showed that visitors almost always got better service. They were seen more quickly and treated more gently, with the cleaners less likely to sneak a bite of them than residents. "Clients can switch partners to enforce a good service," he says.

The canny adjustments to the coral reef free market don't end there. Bshary has found that cleaners are less likely to cheat when another fish is watching, and that they never do when

"In one recently unearthed biological market, the traders have no brains at all"



OLIVIER SILVEN

the client is a predator. Most recently, observing around Lizard Island in Australia, Bshary and his colleagues noticed that cleaners had stopped giving visitors priority access. The reason, he suggests, is that several cyclones and an El Niño climate oscillation killed off 80 per cent of its cleaner wrasse. It has suddenly become a restricted market and the cleaners know it. There's nothing to stop them from making visitors wait.

"I was optimistic that the market paradigm would work in this system," says Bshary. "But the sophistication continues to surprise me. These fish are constantly adjusting to market conditions and updating their strategies accordingly."

That they can do so with tiny brains challenges the idea that only creatures with weighty lumps of grey matter are capable of complex behaviour such as responding to shifts in supply and



demand. “One of the lessons here is that we are probably going to have to rethink that,” says Bshary. “We now see that, at least within ecologically relevant contexts, pretty much any animal can show high levels of sophistication in terms of their behaviour.”

Indeed, over the past few years, biologists have shown that scores of animals are capable of responding to market forces, including chimpanzees, macaques, mongooses, ants, wasps and small fish called cichlids.

In one of the most recently unearthed examples of a biological market, the traders don’t have brains at all. Kiers studies the underground marketplace in which mycorrhizal fungi trade phosphorus for carbon with the roots of plants. This is the perfect environment for market dynamics to emerge, she says, because a single fungal network can be

connected to many plants and switch between trading partners rapidly. The plants in turn can choose from many competing fungal strains.

Sure enough, as Kiers tracked exchanges in these underground networks, she discovered all kinds of economic shenanigans. She and her colleagues employed a series of choice experiments, in which a fungus is connected to several hosts at once. These showed that the fungus will avoid trading with plants growing in the shade, for example. “The fungi are avoiding bad trading partners,” she says. But that is far from the fungi’s most cunning ploy. Kiers has also caught them hoarding resources, storing their phosphorus in a form that is inaccessible to the plants. “In doing so, they can artificially inflate the price, getting more carbon in return from the plants,” she says. “It’s a brilliant strategy.”

But what is really going on here: is a fungus acting rationally in a way Adam Smith would never have thought possible?

That depends on how you define rational. We know that trading strategies can be determined by evolved mechanisms, not just cognitive means. These are “less flexible, but have been tested and fine-tuned by natural selection”, says Noë. “This means that when they are used in situations in which the species at hand find themselves frequently, these strategies can yield better results.” Even the simplest organisms operating in markets can give the impression of rational self-interest.

Still, animals, plants and fungi can’t match the complexity of humans’ economic behaviour. As far as we know, they don’t employ a common currency, for instance.

But that can make them all the more revealing. “While primates are undoubtedly more interesting to watch, fungal-plant systems can be precisely manipulated and trades can be tracked,” says Kiers. “We can watch trade strategies evolve, study tipping points for when and how trade relationships break down.”

Kiers’ work has recently attracted attention from Albert Menkveld, a finance researcher at the Free University of Amsterdam. Menkveld is interested in how best to police and regulate high-frequency trading, in which algorithms compete against each other to make profitable trades on split-second timescales. Since both fungi and algorithms are competing with trading partners in similarly uncomplicated ways, it might be possible to use the fungal system to better understand how so-called “flash-trading” markets will respond to certain strategies.

For Kiers, the most interesting thing about studying mycorrhizal fungi is that it reveals trading strategies uncontaminated by cognition. “These are pure economic decisions, nothing to do with resentment or hope or anything like that,” she says. “Here we can witness economic behaviour in its most pure and ancestral form.” ■

Daniel Cossins is bullish

Strange snow

Ice has many incredible guises, and some can make us feel quite magical, says Padma Nagappan

SUN DOGS

You aren't seeing triple. Sun dogs, brightly coloured blobs of light sometimes visible on either side of the sun (pictured below), are really mirror images of our star.

They appear when it is cold enough for tiny ice crystals to be present in the atmosphere. The illusion is the result of sunlight bending or refracting through these floating crystals, which act as prisms. Consequently, sun dogs are rainbow-hued: the inner edges, closer to the sun, are tinged with shades of red, while the outer edges are blue. They belong to a group of optical phenomena called halos, which all involve sunlight interacting with ice crystals.

Sun dogs are officially called parhelia. Their more common name derives from their appearing to follow the sun, like a dog follows its master. The best time to try to spot them is when the sun is close to the horizon, around sunrise or sunset.



HENRI KOSKINEN/ALAMY

FROST FLOWERS

A truly rare sight, these beautiful but short-lived ice sculptures form when the sap inside plants freezes. This can happen when the air temperature is freezing, but the ground is not yet frozen. The sap inside long-stemmed plants expands in the cold, creating cracks in the stem. Now water can ooze out and freeze, forming intricate and fragile ribbons or flower-like structures (pictured above).



SNOW ROLLERS

As big as an oil barrel or as small and fragile as a stick of candyfloss, snow rollers (pictured right) form on windy hillsides when strong gusts blow moist snow along the ground. "You get a chunk of snow that peels, bends and curls over itself," says Jeffrey Deems at the National Snow and Ice Data Center in Boulder, Colorado. The result is a hollow, cylindrical roll of the stuff with a thin, weak inner layer. Depending on its size and shape, it might be called a snow roller, a snow bale or a snow doughnut.

Snow rollers are rare, with sightings every few years only when conditions



DAVID JONES/PA ARCHIVE/PA IMAGES



NATURE AND SCIENCE/ALAMY

are just right. First, there needs to be a thin surface layer of wet snow. Underneath that, there has to be a layer of powdery snow or ice so the surface layer can lift up and roll as the wind blows without sticking to it. The wind must have a Goldilocks element to it, too – it must be strong enough to lift and roll the snow, but not so strong as to blow the roller away.



MARTIN RUEGNER/GETTY



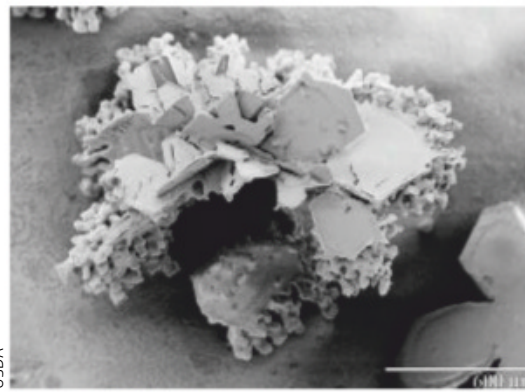
HOAR FROST

The name derives from the Old English word *har*, meaning white or grey with age, because hoar frost deposits its long, spiky crystals onto objects like trees and fences, transforming their appearance. Like regular frost, this variety (pictured above) forms when water vapour turns to ice on a surface that is below freezing. If there is a high-enough deposition rate, which depends on moisture and temperature gradients from the atmosphere to this surface, says Deems, the crystals can grow into the feathery kind typical of hoar frost.

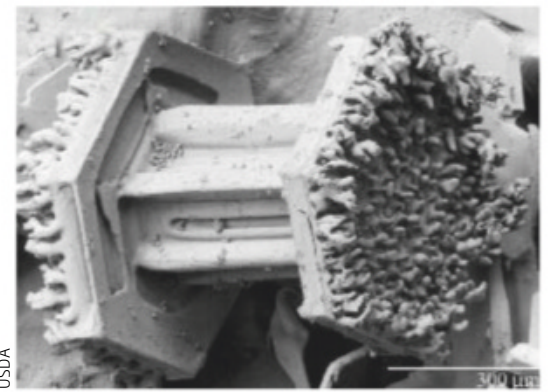
Because the interlocking patterns of crystals grow in size and complexity, some nickname the phenomenon “frost on steroids”.

When it forms on snow, the result can be a giant field of feathery crystals called surface hoar.

Rime on snow crystals seen through an electron microscope (top two images below). If a crystal is entirely covered by rime, it becomes graupel



USDA



USDA



ROLF NUSSBAUMER PHOTOGRAPHY/ALAMY

GRAUPEL

Graupel (pictured above) is perhaps the ultimate whimsical weather phenomenon, a case of unorthodox snow that forms inside a cloud. More precisely, it involves supercooled water droplets condensing on top of falling snowflakes. The droplets freeze, and as they do so they change the shape of the snowflakes, turning them into small squishy balls or pellets. “When you get a snowflake forming in the cloud, the liquid water inside the cloud freezes on to the snowflake as rime, and then it hits the ground as graupel,” Deems says.



RIME

The thick layer of styrofoam-like ice sometimes seen on top of parked cars, trees and telephone poles is called rime (pictured above right). It tends to form straight on to surfaces in cold, foggy environments with lots of water vapour in the air.

For this to succeed, the tiny droplets of cloud or fog must be supercooled – in other words, cooled to below freezing point but able to stay liquid, often thanks to impurities in



PLAINPICTURE/GANGUIN

the water. When these droplets then come into contact with any cold object, like a parked car, they immediately freeze on to it.

Lasting fog can lead to huge build-ups of rime. When it forms from supercooled water vapour turning directly to ice, “it looks like spiky, sparkly crystals”, says Deems, but if the process involves tiny droplets freezing, the rime has a chunkier consistency because the resulting ice crystals are randomly oriented. ■

Padma Nagappan is as cool as ice

Penguin archaeology

It's amazing what you can discover about a penguin when you rummage through its waste, finds Claire Ainsworth

AS EUREKA moments go, it wasn't the most dignified. David Lambert lost his footing and face-planted into a patch of expired penguins. He had been taking blood samples from living birds at a nesting site, but as he scrambled to his feet, it dawned on him that he was standing on a mass grave. "In those penguin colonies you are literally walking on matted bodies," he says. "When you scratch around, you just find bones after bones after bones."

Lambert's insight was to realise that he had stumbled on a deep-frozen archive. The remains belonged to Adélie penguins, which return to the same spots to nest year after year, often for centuries. And this was Antarctica, the coldest, driest place on the planet, offering the ideal conditions for preserving DNA. By digging into this repository, he could unearth the story of Adélies and their evolution.

That's not all. This frozen treasure trove has the potential to give new insights into the past, present and future of the Antarctic, too. This promise is what's drawing scientists like Lambert to the bottom of the world, braving seat-of-your-pants helicopter rides and vicious polar storms to sift through layers of mummified penguin bodies and reeking semi-fossilised bird faeces. And what they are finding has exceeded expectations. The preserved Adélie remains are providing clues about past climate conditions, changes in ice shelves and sea ice, the impact of

historical human activities such as whaling, and even the mechanism of evolution itself. Not bad for a short, stout bird with a reputation for belligerent curiosity.

Three quirks of Adélie life make all of this possible. First is the location of their colonies. Unlike Emperor penguins – the only other truly Antarctic penguin species – Adélies can't nest on ice. They need bare ground with easy access to the sea and a plentiful food supply. So if you find a relic colony and can work out how old it is, you can be pretty confident there was no ice around at that time.

Next, there is the content of the nesting sites. Forget the idyllic pictures on Christmas cards – real-life penguin colonies aren't pretty. "They are incredible places of birth and death," says Lambert, an evolutionary biologist at Griffith University in Brisbane, Australia.

Adélie penguins spend the winter offshore, foraging. Each October, as the Antarctic summer takes hold, monogamous pairs reunite and rebuild their nests – mounds of small stones that keep their eggs off the freezing ground. Colonies can be huge, containing hundreds of thousands of pairs. Over the coming weeks, the debris

"Forget the idyllic pictures on Christmas cards – penguin colonies aren't pretty"





builds up: guano, eggshells, rotting food scraps, and the sorry little bodies of chicks lost to the elements or injury, tangled with those of dead adults.

Once the chicks are fledged, the survivors depart, returning next summer to repeat the cycle. In this way, successive generations of these waddling curators have unwittingly amassed an archive of Adélie existence extending back 50,000 years or more – to when humans were still chipping away at stone tools.

Cryogenic preservation

Crucially – and this is quirk number three – unlike other creatures that have left frozen remains, such as woolly mammoths, Adélies are still around, so ancient samples can be compared with modern ones. “It’s a remarkable record,” says Steven Emslie at the University of North Carolina Wilmington.

Evidence that penguin remains might reveal past environmental conditions first came in the mid-1990s. That was when a team led by Carlo Baroni at the University of Pisa in Italy compared the age of relic colonies along the Ross Sea coast determined by radiocarbon dating with temperature records stored in Antarctic ice cores. They discovered a boom in penguin colony formation between 3000 and 4000 years ago, indicating that a reduction in ice had given the birds easier access to the coast. This penguin heyday coincides with warmer temperatures recorded in the ice cores.

Subsequent studies have helped build a picture of Adélie antics since the last “interglacial”, or warm period, some 44,000 years ago. Intriguingly, the colonies go missing from the Ross Sea coast between about 27,000 and 13,000 years ago. This corresponds with the last ice age and confirms the hypothesis that the world’s largest ice shelf, the Ross ice shelf, expanded at that time, closing off the coast, before retreating once the climate warmed, allowing the penguins to return. Where they went in the intervening millennia remains a mystery.

Penguins haven’t just left a record of themselves, though. Mingled with their remains are those of their prey. “They ➤



are essentially sampling the marine environment for us," says Emslie. Which sounds very kind, until you realise that the samples are provided as smelly deposits of ancient penguin faeces, or guano. It is worth holding your nose and delving in, however, as prey remains reveal past foraging conditions. This helps explain why colonies appear and disappear from the fossil record. "They are blinking in and out throughout an area, based on the local conditions, sea ice conditions, access to open water, krill availability and fish availability," says Emslie.

Careful sifting of guano yields bits of squid beaks, fish bones and "otoliths" – tiny stone-like structures from the inner ears of fish – which provide clues about the size of Adélie prey, their relative abundance and how this shifted over time. Emslie and others have found that the ratios of certain isotopes – heavier or lighter versions of elements such as oxygen – in otoliths can reveal the surface temperature of the sea at the time the fish lived.

Guano also contains DNA, which can open a window on ancient ecology. Lambert's team, for example, is sequencing DNA from a series of guano layers to find out how the birds' diet has changed, so providing an insight into predator-prey relationships over the past 30,000 years. "The only way you can do that is from the penguin guano, because the penguins feed out there and they collect it all," he says.

Historical human activity has left its

"Smelly deposits of ancient penguin faeces reveal past foraging conditions"

mark, too. Emslie's studies of isotopes in ancient penguin eggshells show that between 200 and 300 years ago, Adélies were eating less fish and more krill.

Around that time, explorer James Cook reported sub-Antarctic islands heaving with fur seals and elephant seals, prompting a stampede of hunters, followed by commercial whalers. The mass killing of these animals removed the main consumers of krill from the ecosystem. Emslie's findings lend weight to the idea that krill populations boomed, shifting the balance of the food web.

Back to the future

Putting all these pieces together is helping us predict how penguins – and the Antarctic – will respond to future human activity and climate change. For example, Emslie has been charting the changing fate of Antarctica's biggest Adélie colony, on the Cape Adare coast in the northern Ross Sea. It was founded some 2000 years ago, and around 800 years later swelled to about twice its present size, probably thanks to marine conditions producing rich pickings. The million-strong colony spilled up onto a rocky terrace above the shore – which was abandoned as

the colony dwindled. Rising sea levels within the next 50 years are likely to inundate the beaches at Cape Adare, and the birds may once again shift to the terrace. They may also move south to old stomping grounds as retreating ice makes them accessible once more. "There's going to be a lot of penguins displaced by sea level rise in the near future," says Emslie.

Changing behaviour is one way of coping with a changing environment. Evolving is the other. From the start, Lambert could see that penguin remains offered a unique opportunity to peek under the bonnet of evolution. "We realised that this was a really good way to measure how fast DNA changes over time," he says.

To do this, he and Baroni extracted DNA from a series of birds dating from the present to more than 6000 years ago, then worked out the rate at which random mutation has occurred. Such "molecular clocks" are used to estimate the timings of key evolutionary events such as when new species emerged. The Adélie's "clock" turned out to be ticking between two and seven times faster than previous calculations had suggested.

The team also studied a small number of DNA stretches to see how different versions of genes – alleles – behaved over time. They found that some had spread, while others had died out, and linked this to colonies interbreeding, perhaps when giant icebergs restricted their movements and forced them to mix. This is the first glimpse of evolution at work in DNA over such a time frame. Now Lambert and his colleagues have their eyes on the ultimate prize: sequencing whole genomes of lots of long-dead penguins and comparing them with those of their living descendants, to see how natural selection has shaped genes over millennia, and how this relates to the changing environment.

A lot has been discovered about Adélies since Lambert had his slippery epiphany. Much of this is down to hard graft and ingenuity, but the scientists know they also owe a huge debt to a legion of feathered research assistants. ■

Claire Ainsworth digs penguins



Adélie penguins nest on rocks, not ice, and they return to the same site each year, often for centuries



Ray burn

Early 20th-century attempts to build a death ray were a dark farce, writes Jeff Hecht

THE enemy wasted no time firing up the death rays once they arrived in Woking. Generated in an almost perfectly insulating chamber, and focused by a parabolic mirror of unknown composition, these scorchingly intense beams of heat energy rained untold destruction on the dormitory town in Surrey, just to the south-west of London. "Whatever is combustible flashes into flame at its touch, lead runs like water, it softens iron, cracks and melts glass, and when it falls upon water, incontinently that explodes into steam," an observer wrote.

This isn't reality – unless something untoward is currently stirring in the ➤



PICTURES NOW/ALAMY STOCK PHOTO

suburbs – but a scene from H. G. Wells's 1898 classic about Martian invasion, *The War of the Worlds*. Where Wells blazed a trail, many others have followed. From the ray guns wielded by Buck Rogers and Flash Gordon to *Star Trek* phasers and the planet-destroying Death Star in *Star Wars*, weapons formed of fearsomely energetic beams have become a sci-fi staple.

What has been largely forgotten are the efforts, over decades in the early 20th century, to make real-world death rays. It is a story of egos, charlatanry, deception – and dark comedy.

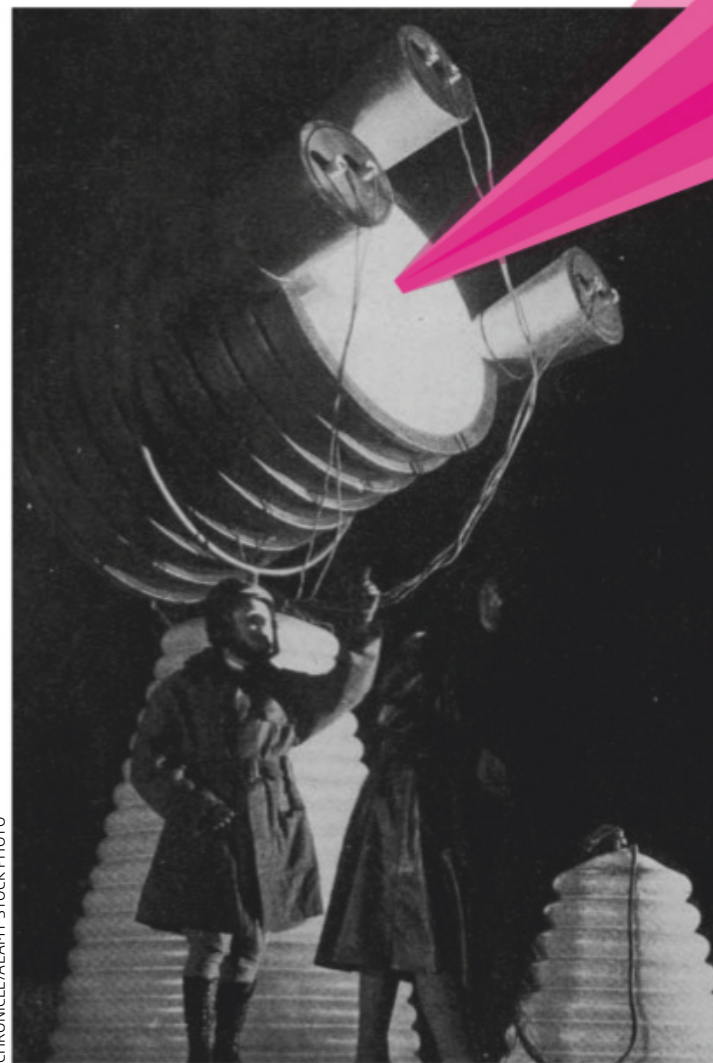
As so often, Wells was ahead of his time, but also very much of his time. At the turn of the 20th century, new types of radiation were in the news. Heinrich Hertz proved the existence of radio waves in 1887, Wilhelm Röntgen produced X-rays in 1895, and alpha, beta and gamma rays soon followed.

In the ensuing years, an arms race developed as Europe drifted towards war – and the new technology loomed large in many a mind. In 1913, a 32-year-old Italian inventor, Giulio Ulivi, claimed that a new form of invisible infrared radiation that he called F-rays could deliver enough energy through the air to detonate gunpowder 16 kilometres away. Armed with F-ray generators, he said, an army could discharge enemy bullets and artillery, detonate their munitions and blow up attacking ships from the shore.

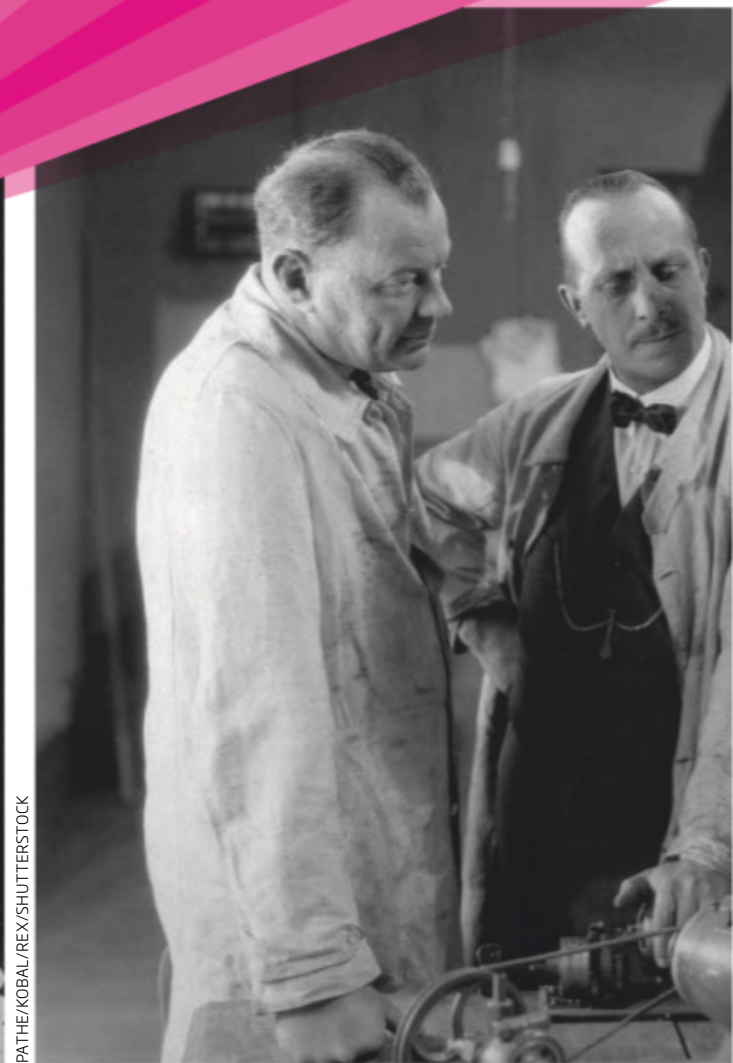
French military officials pricked up their ears, but lost interest when Ulivi wouldn't let them control a test. The Italian navy, meanwhile, gave him money to build a lab. By 1914, Ulivi claimed his F-rays had blown up mines and torpedoes in an Italian river, and a public test was scheduled.

By now, though, things were highly charged in another sense. Ulivi had fallen in love with Maria Luisa Fornari, the daughter of the Italian admiral supervising the experiments. The admiral insisted Ulivi finish his work before marriage, but the couple instead eloped, amid accusations that Ulivi had rigged his tests by spiking the explosive with sodium that exploded when water leaked in. Certainly it seems he only used his own explosives, and his tests only ever worked under water.

Others were also lured by the ray



CHRONICLE/ALAMY STOCK PHOTO



PATHE/KOBAL/REX/SHUTTERSTOCK

technologies. On the other side of the Atlantic, they fascinated Nikola Tesla, the electrical engineer and polymath. The same year *The War of the Worlds* was published, he had used radio waves to control a model boat, and in 1899 showed he could send electricity short distances through the air. He soon claimed he could beam electric power across the Atlantic, and in 1901 talked financier J. P. Morgan into giving him \$150,000 – more than \$4 million today – to build the 57-metre-high Wardencliffe tower on Long Island near New York to show it off.

Electric air

The physics was dodgy, and Tesla burned through the money before he could test the idea. In March 1916, with the US yet to enter the first world war, Tesla told *The Electrical Experimenter* magazine that he could detonate explosives hundreds of kilometres away with wireless power. The magazine's cover, headlined "The Tesla Destroyer", shows a heat-generating tower on the shoreline and ships exploding out at sea. It may have been

The death ray invented by Harry Grindell Matthews (rightmost figure) never fired on all cylinders

a last-gasp attempt to drum up more publicity and cash: in 1917, Tesla's creditors had the Wardencliffe tower torn down for scrap.

It was left largely to a British inventor and entrepreneur called Harry Grindell Matthews to continue flying the flag for death rays. He was a veteran of the Boer war in South Africa, which in 1901 had seen British forces using Guglielmo Marconi's newly minted radio telegraphs to communicate. In 1909, then 29 and living with his mother in Rudgeway just north of Bristol, Grindell Matthews patented a wireless radio telephone system. He raised money to found the Grindell Matthews Wireless Telephone Company, which by 1911 was offering "Aerophones" with an 8-kilometre range for under £20, equivalent to around £2000 today.

The company failed in 1914, and a series of largely unsuccessful military and business ventures followed. But the advent of aerial and rocket warfare during the first world war saw a further uptick of interest in death rays as a means of countering enemy attacks from the sky. "Under the attack of these electric waves the airplane will fall as



though struck by a thunderbolt, the tank will burst into flames, the dreadnought will blow up, poison gas will be dispersed," wrote French Army chief general Marie-Eugène Debeney in *The New York Times* in September 1921. When several French planes flying over Bavaria were forced to make emergency landings in 1923, French officials suspected Germany had a wireless electric ray weapon, spurring a desire to have one of their own.

Sensing an opportunity, by 1924 Grindell Matthews was divulging to a London meeting of the Foreign Press Association details of an invention that would, he said, make war impossible. His death ray would ionise air by illuminating it with ultraviolet light so it could conduct electricity. Press reports claimed it could stop planes, ignite their wings, destroy one in 5 seconds or even wipe out whole armies. Upon hearing that the ray had killed a mouse from 20 metres away, on 24 April 1924 Winston Churchill – at the time out of office, Parliament and party, but soon to become chancellor of the exchequer – wrote to a friend, the physicist Frederick Alexander

Lindemann, that it was worth investigating, but "it may all be a hoax".

The idea wasn't daft: ultraviolet light can ionise atoms in air, and the ions do conduct electricity. But it meant concentrating the ultraviolet light along the whole path to the target, and cranking the voltage to a level enough to fire a deadly bolt of electricity. On 26 May, following questions in Parliament, a demonstration was set up at Grindell Matthews's London lab. The best the death ray could do was stall a motorcycle engine about 14 metres away. The Air Ministry was unimpressed, but offered to pay Grindell Matthews £1000 if he could stop a larger engine in a government-run test.

Himself unimpressed by the level of this largesse, Grindell Matthews hotfooted it to Croydon aerodrome, south of London, to head for Paris. In a veritable French farce, his British investors set out in pursuit brandishing an injunction barring him from leaving the country. He had taken off before they got to Croydon.

In France, Grindell Matthews made an 8-minute silent film promoting his death ray that was shown in London and New York movie theatres. To a jolly piano accompaniment, the inventor shows how it wirelessly lights a bulb and detonates a small pile of gunpowder. Words flashed on the screen claim that "Within 15 Years The Machine Gun will only be found in Museums" and "Thus the Grindell-Matthews Death Ray, in the future, may control the destiny of the world".

Doubts soon surfaced, however. The physicist Ernest Rutherford, who had discovered alpha, beta and gamma rays, warned government officials to avoid Grindell Matthews. A former collaborator, Irish physicist E. E. Fournier d'Albe, called the death ray a "myth" that the British public wanted to believe because of the scars left by the first world war.

With no credible results to show, death rays faded from the news.

"The best the death ray did was stall a motorbike engine 14 metres away"

Grindell Matthews spent a few years in the US promoting other unsuccessful inventions, but by 1932 was back in the UK. Owing creditors more than £11,000, he told a bankruptcy court he had earned only £3300 since 1924. Prosperity finally arrived in 1938, three years before his death, when he married the wannabe opera singer Ganna Walska, whose previous four husbands included a couple of millionaires.

Trump card

In the 1930s, with another war looming, the British Air Ministry decided the best defence against enemy bombers wasn't zapping them down, but targeting them with radar that could direct anti-aircraft fire. But it didn't shut the door completely: the ministry still offered £1000 to anyone who could demonstrate a death ray that could kill a sheep from a hundred yards away. It seems no one could.

In the US, Tesla still occasionally talked about death rays, and in 1934 he announced he had invented a "death beam" that would fire a beam of tiny particles as far as Earth's curvature allowed. When he died in 1943, the US War Department sent an expert on high-voltage engineering from the Massachusetts Institute of Technology, John G. Trump, to go through his papers for anything of military interest. The professor found that in 1935 the Soviet Union had paid Tesla \$25,000 for his plans, but never got the thing to work. Nothing else was of much military value, Trump wrote: most of Tesla's highly regarded work had been done in the previous century, and his more recent ideas were largely speculative.

The professor's nephew, the current US commander-in-chief Donald J. Trump, is famously proud of his big nuclear button. Yet despite billions of dollars spent on energy weapons, the unstoppable death ray remains out of anyone's reach. Unless some alien civilisation has cracked it: citizens of Woking, stay woke. ■

Jeff Hecht plans world domination with the forthcoming *Lasers, Death Rays, and the Long, Strange Quest for the Ultimate Weapon* (Prometheus Books)

No teddy bears' picnic

When Earth got chilly, cave bears lacked what it took to survive. Chris Baraniuk investigates

IF YOU go down underground today, look out for a big surprise. If you go into a cave, anyway, be sure to adjust your eyes. For many caves, in Europe at least, contain the remains of a curious beast. It's not an olm or a bat that's deceased – it's a cave bear.

Cave bears died out at least 24,000 years ago, but they were once very common. In fact, they left so many bones that during the first world war, they were used to provide phosphates for fertilisers and bombs. Plenty of skulls and skeletons still remain in caves across a swathe of Eurasia, from Spain to south-central Russia, and this treasure trove has allowed palaeontologists to piece together the bear's story. We know, for example, that males could reach a whopping

WIEBKE



1000 kilograms – up to four times the weight of females. Footprints, claw marks and fur imprints reveal that, in winter, some settled on terraces and entered a deep sleep known as torpor, waking periodically to drink from water sources inside their caves before returning to their resting places. We even know that Neanderthals hunted cave bears, ambushing them as they awoke in the spring. But one mystery remains. Why did they go extinct?

Cave bears evolved around 1.5 million years ago from a common ancestor with brown bears and polar bears – in fact, their DNA lives on in modern brown bears, revealing that the two species must have interbred. They lived during the Pleistocene, a time when Earth's climate endured a series of

fluctuations, including relatively rapid changes – within 1000 years – from hot and dry to cold and wet. One such ice age occurred around the time cave bears died out. Could this have played a role in their demise? Danielle Schreve at Royal Holloway, University of London, notes that it would have put significant ecological stress on large animals. Nevertheless, some of the bear's competitors – including brown bears, wolves and lions – managed to survive, hinting that they possessed something cave bears lacked.

"Instead of getting smarter, cave bears got fat to doze through the harsh winters"

Suspicion has fallen on the cave bear's diet. "There are some big, more flexible predators around that are doing very well," says Schreve. Wolves and lions are both unfussy carnivores. Brown bears are omnivorous. But cave bears seem to have been herbivores. They have powerful jaws and their teeth are broader than those of brown bears, making them well adapted for grinding up plant-based foods, explains Hervé Bocherens at the University of Tübingen in Germany. He notes that, as the climate became colder and plant life dwindled, this constrained diet might have made it difficult for them to build up enough fat to survive the long winter months in their caves.

"Their diet is so interlinked with ➤



ULLSTEIN BILD/GETTY



plant availability – that seems to have been one of the things that really knocks them on the head,” says Schreve. She thinks that in the UK, where cave bears died out far earlier – around 350,000 years ago – the impact of climatic changes may have been greater. In these conditions, where the weather was unforgiving and food resources favoured more mobile species, perhaps brown bears had the upper hand, she says.

It makes sense. But there’s a twist: cave bears may in fact have been secret omnivores.

Marius Robu at the Emil Racovita Institute of Speleology in Romania and his colleagues examined remains recovered from Peștera Urșilor, a famous cave bear site in the country. They were looking for an isotope, nitrogen-15, which is generally more abundant in the bones and fur of omnivores than herbivores. Their analysis of cave bear bone collagen revealed plenty. In fact, they found that the levels were the same as in fur from omnivorous grizzly bears collected between 1989 and 2009 in Yellowstone National Park in the US. Robu suspects that the cave bears were sometimes herbivorous but, depending on their circumstances, they occasionally ate meat. He and his colleagues now have data from four other sites in Romania all showing similar nitrogen-15 levels.

Bear diets are often adjustable. Even pandas, with their overriding penchant for bamboo, occasionally eat meat. Nevertheless, not everyone is convinced that the elevated nitrogen-15 levels mean that cave bears were omnivorous. “Mammoths are herbivores for sure and they have the same values as these bears,” says Bocherens. In research published earlier this year, he argues that cave bears could have absorbed the isotope from herbaceous, grass-like plants called graminoids, or from fungi.

But there may have been another nail in the cave bear coffin. A study

Although long extinct, cave bears (above) live on in the DNA of brown bears (below), with which they once interbred



DOUG LINDSTRAND/GETTY

comparing the skulls of 10 living and extinct species of bears has revealed that cave bear brains were remarkably small. Calculating “encephalisation quotient” – brain size as a proportion of body size – Kristof Veitschegger at the University of Zurich, Switzerland, found the Malayan sun bear to be the genius of the group with an EQ of 1.31. For brown bears, the figure is 0.83, and cave bears came bottom of the class with an EQ of just 0.60. (In humans, by comparison, it is 6.56.)

A bear of very little brain

Veitschegger’s analysis indicates that although the cave bear got bigger over time, its brain did not grow. Two factors conspired to make this happen: diet and dormancy. Mammals living in a highly seasonal environment usually evolve to eat a flexible diet, but dormancy during winter makes this unnecessary – they can rely on body fat stores instead. However, the energy that goes into fat storage isn’t available to grow a big brain. And because brain tissue is expensive to produce and maintain, the cave bear’s low-calorie, plant-based diet would have imposed further constraints. Veitschegger thinks that cave bears made a trade-off: instead of getting smarter, they got fat to doze through the harsh winters. But it turned out that the ice age wasn’t something they could sleep off.

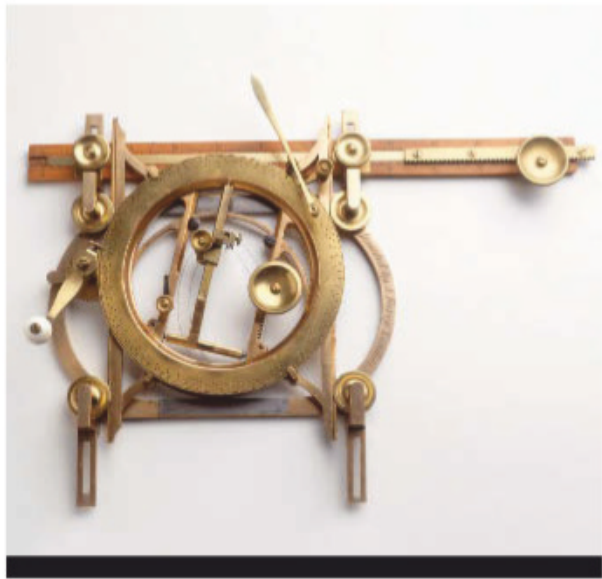
The brain-size question is interesting because it’s not something that has been explored previously, says Schreve. “It fits quite well with the other evidence, but I think it’s only a part of the story.” She points to several studies showing that cave bears were becoming less genetically diverse as time went on – a tell-tale sign that they were struggling to adapt in general.

Although debate remains, it seems clear that cave bears were victims of their inability to adapt. They got stuck in their ways, leaving them unable to keep up with a drastically changing climate. As a result, this once-dominant beast went the way of the dodo. There may be a lesson in there somewhere. ■

Chris Baraniuk is bearing up well, all things considered

Antiques quiz show

Can you work out the purpose of these historical inventions?



CLIVE STREET/OK/GETTY

1.
A. Machine for cutting circular panes of glass
B. Device for adjusting 19th-century dental retainers
C. Tool for drawing ellipses
D. Guillotine calibrator



NATIONAL TRUST FOR SCOTLAND

2.
A. Light bulb tester
B. Laser-based roulette wheel
C. Second world war signalling device
D. Device for calculating alcohol content



MARKUS MATZEL/ULLSTEIN BILD VIA GETTY

3.
A. Executive toy for a Chinese emperor
B. Seismometer
C. Combustion-powered clock
D. Magnet-powered model rowboat



CHRIST CHURCH LIBRARY © MHS, UNIVERSITY OF OXFORD/INVENTORY NO. 31922

4.
A. Globe for flat-Earthers
B. Device for constructing sundials
C. Pocket astrolabe
D. 18th-century gyroscope



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5.
A. Pill roller
B. Lint remover
C. Iron for collar ruffs
D. Shoe polisher



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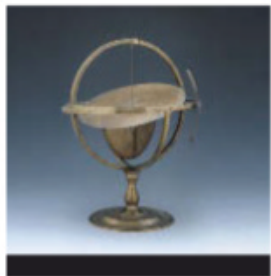
6.
A. Earliest toy railway carriage
B. Elevator winch
C. Victorian roller skate
D. Steam locomotive adhesion tester

Answers on next page ➤

ANSWERS



1 C. This is an ellipsograph: a tool for precisely drawing circles, ellipses and various parallel, radiating and spiral lines. It may sound trivial, but its invention represented a vital advance in the standardisation of machinery, allowing engineers to quickly and accurately draw templates for the teeth of cogwheels and the threads of screws. The device also found use in preventing the forgery of banknotes, rendering precise patterns that were extremely difficult to replicate by hand. This ellipsograph, from 1818, was constructed by Joseph Clement, a mechanic later hired to construct Charles Babbage's advanced mechanical calculator, the Difference Engine.



4 B. You would be forgiven for thinking this invention is some sort of sundial. In reality, however, it is a "dialling sphere", built to allow you to construct your own. The thin plate is tilted and rotated according to where the dial will be placed. Then, simply by moving a candle around the sphere, the shadow cast by the vertical string simulates the sun's motion across the sky. This particular dialling sphere was made in the early 18th century by John Rowley. His claim to fame was the construction of a clockwork model solar system that acquired the name of the person who commissioned it, the 4th Earl of Orrery, though neither he nor Rowley were the inventors.



2 D. If you ever felt like your whisky was being diluted on the sly, these so-called philosophical beads would help you find out for certain. Also known as gravity beads or hydrostatic bubbles, these numbered glass spheres were plopped into a liquid in ascending order until one floated, allowing the user to assess its specific gravity. They were invented in 1757 by a Scottish astronomer named Alexander Wilson to compare spring water, but alternative uses soon emerged. According to the instructions that came with this particular example, number 22 should sink in whisky, number 25 in rum and number 27 in brandy or gin.



5 A. Before the days of off-the-shelf medicines, chemists would make their own remedies in-house. One invaluable tool was a pill roller such as this, designed to produce individual tablets. The pharmacist would crush dry ingredients together with syrup to form a paste, perhaps adding a bit of charcoal to purify the breath. The flat side of the pill roller's paddle was used to roll the paste out into a long tube on the flat wooden part, like a rolling pin smoothing dough. The tube of paste was then rolled between the grooved sides of the surface and paddle, separating it into equal spherical pills ready for swallowing.



3 C. This invention, while resembling a fearsome rowboat, is in fact a Chinese fire clock. Known to have been used as early as the 6th century, such clocks worked by having an incense stick placed inside their central trough. Once lit at one end, the stick would burn from bow to stern, eating through the threads at regular intervals and causing each pair of weights to noisily drop onto a surface below. While this particular clock, dating from the 19th century, kept time by regular clangs, others would use layered incense sticks, so that the passage of time could be tracked by sudden changes in smell.



6 D. It looks like a child's oversized Meccano construction, but this device played a key role in the development of train travel. On the earliest railways, stationary steam engines located at one end of the track hauled carriages along by a cable. But as engines became ever more efficient, they could be put on wheels themselves. The problem was designing rails to reliably carry them. One solution was to have a pinion engaging with teeth along the track, but this was inefficient and expensive. In 1812, William Hedley used this human-powered model carriage to test whether coupling the wheels – having them counteract each other if one pair began to slip – would allow a locomotive to adhere to smooth rails. In 1813, he successfully put it into practice with Puffing Billy, now the oldest surviving steam locomotive. ■

Anton Howes (@antonhowes) is a master of inventions

R toys us?

Childhood play objects may have shaped the course of human history, finds **David Robson**



KELLY DAVIDSON/PLAINPICTURE

Playing fosters imagination, a crucial ingredient in technological innovation

have their roots in children's toys.

The idea that toys shaped humanity builds on a growing understanding of just how important play has been to the evolution of our brains. Analyses of remains such as teeth from ancient hominins show that our species, *Homo sapiens*, enjoys an unusually long childhood. An extended infancy gives more time for imaginative play, which has been shown to train many important cognitive skills, including counterfactual thinking – the ability to ask “what if...” – and the capacity to envisage different scenarios. According to April Nowell at the University of Victoria in Canada, this might explain why we are the only species with such a rich symbolic and artistic culture.

Surprisingly, however, no one had examined toys in the archaeological record as objects that might have influenced the cognitive development of our ancestors – until Riede was inspired by the rising tide of plastic around his sons. “As soon as you have children, your home becomes flooded with playthings,” he says. This is not limited to the West: in almost every modern society, children play with miniature versions of adult objects.

A few psychological studies have shown that the characteristics of toys can have a direct influence on the cognitive development of children. In one experiment, kids playing with open-ended toys – building blocks that can be put together in many different ways, rather than ones forming a particular structure – tended to be better at solving so-called “divergent” problems. These require us to generate many solutions, such as finding new ➤

FEW origin stories are as perplexing as the invention of the wheel.

Thomas Edison famously claimed that genius is 1 per cent inspiration and 99 per cent perspiration – for our ancestors, it was the 99 per cent that posed a problem. Even after they realised they could move objects with a rolling motion, they needed to refine their engineering skills enough to build a wheel that actually worked.

“Making a full-scale wheel takes a lot of physical resources, it takes a lot of time, it takes a lot of skill,” says Felix Riede, an archaeologist at Aarhus University in Denmark. But how could any prehistoric inventor have afforded to pour so much blood, sweat and tears into experimentation

when there were mouths to feed?

Inspired by his young son, Riede has come up with a surprising solution. He thinks that the skills required for technological innovation were honed through play. While the adults went about the serious work of ensuring the group's survival, youngsters naturally experimented with the objects around them. If Riede is right, some of humanity's most important inventions – including the wheel, weaving and projectile weapons –

“Some of humanity's key inventions could have their roots in children's toys”



uses for a familiar object. Playthings can also help a child understand mechanical properties, such as the motion of a rolling ball, and practise social roles, such as parenting a doll. "Toys facilitate and also limit the kinds of cognitive activities and thinking that children engage in," says Riede.

According to his hypothesis, prehistoric toys allowed children to explore new uses and adaptations of familiar objects while they played. This would have equipped them with greater technological understanding and the more-flexible outlook that underpins greater creativity. "It's this cognitive priming that loads the dice in favour of an innovation that actually works," says Riede. If he is right, you would expect to see some trace of this process in the archaeological record, with the presence of certain toys somehow pre-empting big cultural shifts in related technologies.

Inspired by play

It is early days for this idea, but Riede, Nowell and their colleagues recently published a paper outlining some intriguing case studies. For instance, examining the archaeological records of communities living in Greenland from around 4500 years ago, they found that the early colonisers lacked toys and also showed little innovation in their material culture, whereas the Thule, who migrated into Greenland around 800 years ago, had many miniature objects that appear to have been designed specifically for child's play, including toy kayaks, sledges, weapons and dolls. Their appearance seemed to coincide with an explosion of new adult technologies, such as advanced designs for harpoons, sophisticated boats and elaborate clothes. The chronology isn't refined enough to determine which emerged first, the toys or the advanced technology, but Riede thinks the two may have grown together, with the richer material culture inspiring new play objects, which in turn primed the young minds for further innovation.

The team also points to sites in Western Cape, South Africa, dating back 60,000 to 80,000 years ago. Analyses of rock fragments suggest that novices,

JASON RAISH

presumably children, were mimicking the adults' stone knapping, producing crude and functionally useless copies of real tools. This "play-copying" again seems to coincide with sophisticated new technologies, including the first arrowheads, suggesting that the childhood games might have sparked greater cultural innovation.

Meanwhile, spinning whorls essential for the production of fabrics

may have been inspired by "rondelles", threaded discs engraved with pictures of animals. Archaeologists believe that these discs, found in Europe during the Late Stone Age, would have spun around the thread to alternate between the images on either side, a bit like a prehistoric flick-book. "There is cognitive overlap between the idea of these spinning discs and the idea that you can use rotation for a purpose – to





FIGHT CLUBS

Team sports have long been known to bring out our tribal instincts. But did they first emerge to train us for warfare? That's the hypothesis of Michelle Scalise Sugiyama at the University of Oregon.

She scoured the ethnographic record for information about the physical strategies used by traditional societies during their typical battles, such as when they raid another camp. Her final list of eight items included moves such as kicking, striking and blocking blows to the body, throwing and dodging objects, and group coordination. "They have to track the behaviours and infer the intentions of multiple individuals," says

Scalise Sugiyama. She then compared this list with ethnographic accounts of team games, many of which resembled Western sports such as rugby.

Sure enough, 36 per cent of the societies played a game incorporating at least half of the strategies that are crucial for battle. Scalise Sugiyama thinks this is probably an underestimate because anthropologists sometimes see such games as trivial activities. "If you're lucky, you get a couple of pages of information," she says. But if team sports do serve an important evolutionary function, we should take play more seriously.

models of animals with holes drilled through their feet for an axle, and ceramic discs that functioned as wheels. The tops of the animals were hollowed, leading to the suggestion that they were ornate drinking vessels, perhaps used during rituals. But given their size and the fact that miniature animals are playthings in many modern cultures, Riede believes that they were toys. "You could easily call them quite cute," he says.

If so, like any toddler with a train set today, children playing with those toys would have been getting to grips with the mechanics of rotary motion. They might have used their toys to carry various objects, and practised different ways of propelling them – from the front or the back, or letting them roll down a slope. They might even have experimented with wheels of different sizes, or made from different materials. As the children grew up, those same skills would have helped them make the cognitive leap necessary to imagine a wagon, whereas a society that lacked those toys would have struggled to envisage a workable design.

Perhaps the early inventors even

used toys to produce prototypes. "You could easily make 100 of these miniature figures, all different, play around with them – quite literally – and then see what sort of design works best," says Riede.

Archaeologist Michelle Langley at Griffith University in South East Queensland, Australia, agrees that the idea is worth further study. "You don't just wake up one day as an adult, able to do all these things. You need to practise and to get familiar with the raw materials and how they work," she says. "There's this big learning process and you need to start young."

Like Riede, Langley has been inspired by her own child's behaviour. She recently published an article arguing that various archaeological objects, including rondelles and clay figurines often seen as ritual objects, should be reinterpreted as playthings. Animal figures, for instance, might have been important to teach children about hunting. "It's easier when you have these little props."

Langley is currently designing a study that will involve giving replicas of prehistoric objects to small children to help determine the characteristic patterns of wear and tear that come with play – whether they become smooth and polished, or cracked and chipped, for instance. This should then allow archaeologists to better identify which artefacts really were toys, perhaps providing further evidence for Riede's hypothesis.

Riede, Langley and Nowell are now planning to organise a conference in Australia that will draw together scientists from diverse disciplines to explore exactly how children, so long overlooked by archaeologists, drove cultural change. Riede is excited about what they might find. "We need to look at the stuff we already have with new eyes and from a different angle because the children's material culture is really important for understanding long-term trajectories of innovation and creativity," he says.

If they are right, our greatest advances might truly have been child's play. ■

David Robson believes this is an idea worth toying with

make fibres," says Riede.

It is the invention of the wheel, however, that offers the most compelling support for Riede's idea. The oldest evidence of wheeled vehicles suggests that the technology emerged around 5500 years ago, across western Eurasia – in the northern Caucasus, Mesopotamia and central and northern Europe. But some two centuries beforehand, we see small

"A society that lacked toys with wheels would have struggled to envisage a workable wagon"

Say thanks, a lot

Don't keep gratitude to yourself. You need to express it to reap the wider benefits, finds **Susana Martinez-Conde**

WITHOUT meaning to sound ungrateful, it really is the comedown after the festive cheer: the dreaded thank-you notes. Perhaps you agonise over how to make each sound genuine. Maybe you put off the chore for so long you end up not bothering, or simply feel they are an outdated waste of time. Then there is the skill of mustering the convincing faux-thanks for unwanted gifts.

If writing thank-you letters is a task you readily dismiss, you aren't alone. It turns out we express our gratitude more rarely than you might assume. But, however you feel about those festive notes, it is time to knuckle down. Because saying thanks could be the best gift you can give, to yourself and others.

The benefits of gratitude have long been championed in religious and philosophical thinking. In recent years, the science has been catching up: it shows that people who feel most grateful generally get a psychological boost as a result. They also have greater life satisfaction, fewer visits to the doctor and better sleep. This has led to gratitude becoming part of our cultural zeitgeist, inspiring a proliferation of gratitude journals, in which you record things you are thankful for, and meditation practices in which you focus thoughts on them. It has also led to renewed interest in the neuroscience and psychology of gratitude (see "The grateful brain", right).

However, the benefits of actually expressing this gratitude have received

less attention. Now evidence is stacking up that shows turning our inner gratitude into action can make our lives even better.

For instance, a simple thank you can build relationships, even with strangers. Take people who have received a note of thanks for something they have done from a peer they don't know. They are more likely to share their contact details with that person in an attempt to continue the relationship than people who receive a note that doesn't contain thanks. A simple thank you seems to signal interpersonal warmth.

Expressing gratitude to a friend also changes your view of that relationship, making it feel stronger. In 2010, Nathaniel Lambert, then at Florida State University, and his colleagues found that people who simply thought grateful thoughts about a friend, or even took part in positive interactions with them, didn't experience the same effects.

But the benefits go further than just strengthening social bonds, they can have an impact on health, too. A study of more than 200 nurses working in two Italian hospitals found that gratitude expressed by patients could protect nurses from burnout. That was especially so in the emergency room, where personal interactions with

"Turning our inner gratitude into action can make our lives even better"



LISA TEGMEIER

patients are typically shorter and less rewarding. This positive feedback from patients reduced feelings of exhaustion and cynicism among nurses, says Mara Martini at the University of Turin, who carried out the work.

All of this makes sense from an evolutionary perspective. Gratitude is a very social emotion. It sends a signal to others that we recognise what they have done, that we aren't just freeloading. It might also imply that we intend to reciprocate.

In light of all this, you might expect that we go out of our way to express our thanks in our daily lives. In fact, the opposite is true: we rarely bother.

To better understand how people



express gratitude in normal life, anthropologist Simeon Floyd, at the Max Planck Institute for Psycholinguistics in the Netherlands and his colleagues staged a large, cross-cultural study spanning five continents and eight languages. They included English, Italian, Polish, Russian and Lao, as well as unwritten languages such as Cha'palaa, spoken in Ecuador, Murrinh-Patha, used in northern Australia, and Siwu, spoken in Ghana. Interactions included both verbal and non-verbal expressions of gratitude such as a smile or a nod.

Floyd's team left cameras in household and community settings and captured more than 1500 instances of social interactions in which one person asked for something and another responded.

They found that in every culture, people overwhelmingly fulfilled requests, but expressions of gratitude, such as saying "thanks" or nodding in appreciation, were remarkably rare, occurring just 5.5 per cent of the time.

English and Italian speakers had slightly higher rates of gratitude expression than others – 14.5 per cent and 13.5 per cent of the time, respectively, but still surprisingly low considering Western ideals about politeness, says Floyd. "English speakers are not so different from other people, and often opt for no expression of gratitude in informal contexts," he says.

Cha'palaa speakers had the lowest frequency of expressed gratitude, with zero examples in 96 recorded

interactions. But this starts to make sense once you learn that the language has no easy way to say "thank you".

Also surprised by the findings was David Peterson, a linguist who developed the constructed language Dothraki for the TV show *Game of Thrones*. It too, has no word for thank you, something Peterson initially believed unlikely. "I thought that you had to have a word to express gratitude," he says.

Overthinking it

One explanation for the absence of thank yous in some languages could be a tacit understanding of our social obligations in informal contexts, such as with close friends and family, which makes explicit acknowledgement less vital.

Or it could be that we simply don't realise the impact on others of saying thanks. In a series of three experiments in 2018 at the University of Chicago, Amit Kumar and Nicholas Epley asked volunteers to write letters expressing gratitude, and to predict how surprised, happy, and awkward recipients would feel. The pair then asked recipients how the letters actually made them feel. The results were disheartening: the letter writers consistently overestimated the awkwardness that recipients felt, while underestimating positive feelings and surprise about the letters and their contents. In other words, even though people really like receiving letters of gratitude, we send them far less often than we should because we underestimate their beneficial impact.

Kumar advises against overthinking your thank yous. "One thing we observe is that expressers are inordinately concerned with how they express their gratitude – how articulate they'll be, whether they'll get the words just right," he says. But those on the receiving end are far less bothered. "Saying something, irrespective of precisely how you go about doing it, could improve your own well-being, as well as the well-being of another person," he says.

High time to drop the excuses and get those thank-you notes done. ■

Susana Martinez-Conde is eternally grateful

THE GRATEFUL BRAIN

One way to find out where gratitude comes from and what it is good for is to try to locate it in the brain.

In one of the first such studies, Glenn Fox at the University of Southern California and his colleagues scanned the brains of volunteers in whom they induced a sense of gratitude by presenting them with acts of kindness that occurred during the holocaust, as recounted by survivors.

The fMRI scans showed a strong overlap between the areas of the brain that are active during feelings of gratitude and those associated with theory of mind – our ability to put ourselves in the shoes of others. We often say that it is the thought behind a gift that counts, the team points out, and the results seem to bear that out.

The brain areas involved in feeling gratitude have also been linked to making

value judgements, fairness and decision-making.

That fits with the idea that gratitude plays a strong, probably evolved, role in our social bonds and networks (see main story).

The feeling of gratitude seems to be about processing the value of another person's contribution to our lives, our motivations to help others and the relief we can feel when someone comes to our aid, says Fox.



Oh, no it isn't!

Scientific disagreements can sometimes descend into pantomime insults, says Richard Webb

OPEN debate and freewheeling disagreement are science's special sauce. But this sauce can sometimes get a little sticky. When the temperature rises, egos inflate, insults bubble over and sparks fly. The clash of ideas becomes the clash of the minds that hold them.

Think Newton against Leibniz on who invented calculus. Or "Darwin's Bulldog" Thomas Huxley against "Soapy Sam" Wilberforce, the Bishop of Oxford, debating evolution. Or Tesla and Edison and the battle for supremacy between alternating and direct current (a battle that indirectly led to the electrocution of an elephant).

Or, indeed, any number of instances of scientists behaving badly in the present day...

AN ASTEROID KILLED THE DINOSAURS Oh no it didn't!

Thankfully, velociraptors and their ilk are now confined to museums and movie theatres, but some of the primal violence of their world seems to have spilled over into the lecture halls where scientists discuss their disappearance.

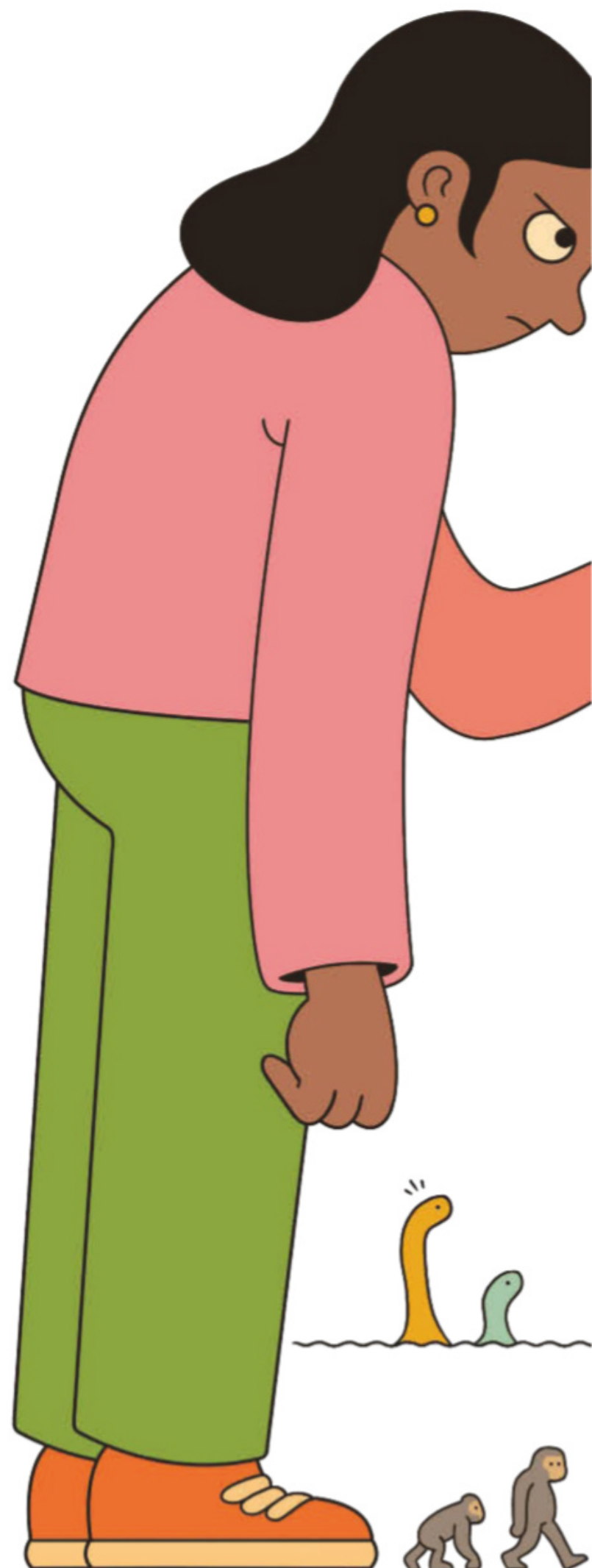
The "dino wars" began in 1980, when Nobel-prizewinning physicist Luis Alvarez and his collaborators, including his geologist son Walter, suggested that a massive asteroid impact had precipitated a global mass extinction 66 million years ago.

They had been measuring levels of iridium, which is a rare element on Earth, thought to be brought here by impacting meteorites. What they found was a huge spike that dated to the time of the extinction in rocks near Gubbio, Italy. Proof positive, said Alvarez, who just two years later declared that the impact's occurrence, and its causal role in the extinction, were "no longer debatable points".

Geologists work on slower timescales, and some were not impressed by a physicist muscling in on their territory. Things got decidedly nasty, and accusations of dirty tricks, wilful deceit and incompetence flew both ways. "I don't like to say bad things about paleontologists, but they're really not very good scientists," Alvarez, by then dying of oesophageal cancer, told *The New York Times* in 1988. "They're more like stamp collectors."

That same year Princeton geologist Gerta Keller entered the debate. "It was one of the nastiest controversies from the get-go," she says. As a relative unknown presenting results refuting the impact hypothesis to a conference of true believers, she found

GIACOMO GAMBINERI





herself a target of the personal vitriol. "It was essentially an attack feast," she says.

In 1990, the discovery of a 150-kilometre-wide impact crater off the coast of modern Mexico dating to around the right time seemed to clinch things for "the impact mafia", as Keller calls them. But she persists in her sometimes lonely war. "I grew up in the Alps, I am a hardy mountain creature", she says. The data just don't fit, she insists. "I ask them why they always lie. All they have is a sexy story, and they know it."

I HAVE THE PROOF

Oh no you don't!

It's as simple as ABC – except when that ABC is the ABC conjecture. Back in 2012, mathematician Shinichi Mochizuki of Kyoto University, Japan, claimed a proof of this problem, variously described by *New Scientist* as "a long-standing pure maths problem" and something that "explores the deep nature of numbers".

In fact, we have regularly reported over the years on the increasingly fraught attempts by mathematicians to verify Mochizuki's dense 500-page proof, without really explaining what it, or the conjecture, involves. That's because we can't. No one can.

Well, perhaps 15 people in the world have mastered the basics of Inter-universal Teichmüller theory, the framework Mochizuki developed for his proof, says Ivan Fesenko of the University of Nottingham, UK. He has emerged as Mochizuki's main cheerleader in the West. According to him, no one who knows enough about the subject to possibly comment has ever found anything to object to.

Objectors include Peter Scholze, a Fields medallist and one of the rising stars of mathematics. The proof has still not made the grade of being published in a journal, despite Mochizuki publishing a potted 300-page summary in 2017. For Fesenko, that is purely down to bad faith. "The authors of those opinions often behave irresponsibly by talking about mathematics they do not know and by misleading other people who cannot distinguish an expert from a non-expert," he says. ➤

PLUTO IS A PLANET

Oh no it isn't!

Perhaps it is just sentimentality, or the influence of Disney's lovable floppy-eared pup, but few scientific decisions have caused as much consternation as when Pluto had its planet status revoked in 2006.

Alan Stern certainly wasn't having any of it. It was an "awful" decision, he told *New Scientist* at the time. "As a scientist, I'm embarrassed."

As head of the New Horizons mission, which had blasted off to Pluto earlier that year, he had more skin in the game than most – a fact astronomer Mike Brown at the California Institute of Technology has never been shy to point out. The New Horizons team just found it "emotionally difficult" they weren't going to a planet, he is on record as saying.

Brown's Twitter handle is @plutokiller, and the discovery by his team in January 2005 of Eris, a body in Pluto's neck of the woods that is by some measures bigger, played a big part in Pluto's downgrading. But limiting planets for the sake of not having too many is ridiculous, says Stern. "Then I guess we're going back to eight US states," he told *New Scientist* back in 2016.

THIS IS THE MISSING LINK

Oh no it isn't!

No collection of scientific feuds would be complete without mention of those studying our human origins, where dusty old bones are ripe for picking. Few of these spats spill out onto prime-time television, but that's exactly what happened when Richard Leakey and Donald Johanson appeared on *Walter Cronkite's Universe* in 1981.

It perhaps didn't help that the human origins of the two adversaries, both then in their 30s, were very different. Leakey came from palaeoanthropological royalty: he was the son of Louis and Mary Leakey, who had convinced the world that Africa was the cradle of humanity. Johanson was the brash American newcomer, son of a barber who had died when Donald was only two.

The beef began in 1974, when Johanson discovered a 3.2-million-year old fossil known as Lucy, which he



NMSU PHOTO BY DARREN PHILLIPS

argued was a "missing link" in our own ancestry, representing the first instance of humans having evolved to walk upright. The Leakeys argued that Lucy couldn't possibly be one of our own.

On Cronkite's programme, years of animosity spilled out as Leakey, challenged by Johanson to produce a hominid family tree to rival one he had sketched, instead drew a big fat cross over Johanson's. Johanson doubled down, leading a dig in Tanzania's Olduvai Gorge where the Leakeys had made their name.

Mary Leakey is reported to have removed the furnishings and equipment from the field station there before his arrival; Johanson meanwhile wrote in 1988 that he was "quite happy not having a legacy to uphold", suggesting Richard Leakey was a hostage to his parents' ideas.

Fortunately, this dispute has a happy ending. In 2011, 30 years older and perhaps wiser, the pair were invited back to share a stage at the American Museum of Natural History where the original drama had happened, talking

Pluto's 2006 reclassification as a dwarf planet struck a nerve

about the great unfinished business of their field – discovering the last common ancestor of humans and chimpanzees.

STRING THEORY WORKS

Oh no it doesn't!

Peter Woit is unusual among scientists: he is known not for proposing an idea, but for opposing one. Since 2002, the mathematical physicist at Columbia University in New York has been the brains behind the blog *Not Even Wrong*.

Its subject is string theory, which proposes that fundamental particles of nature are not particles at all, but little rolled up balls of string. These exist in a universe of at least 10 dimensions, some of them also rolled up too tightly for us to see. What's more, our cosmos is just one of a multiverse of 10^{500} universes, each slightly different from the last.

This might sound ropery to an untrained ear. But for many physicists, string theory remains the most reasonable way to unite our conflicting pictures of reality under one umbrella, a "theory of everything".

Alternatively, it is just ropery. "It never seemed that promising to me," says Woit. "I thought somebody should explain this isn't really working out how it was supposed to." Not only has the theory failed in 50-odd years to produce any testable prediction, but machines such as the Large Hadron Collider have failed to turn up any evidence for anything that might indicate it is pointing in even remotely the right direction. So, not even wrong.

It's nothing personal, says Woit: "I have a lot of friends who are string theorists." But his critical stance, cemented in a book he wrote back in 2006 also titled *Not Even Wrong*, has repeatedly put him in the academic crosshairs. Some have dismissed him as a crackpot, or questioned his qualification to comment on matters of theoretical physics from an office in a maths department.

In the main, though, this has been a decorous disagreement by the standards of badly behaved science – after all, it's only the nature of the universe that's at stake. "One Harvard faculty member did publicly call for my death," says Woit. "But he soon left Harvard." ■

Richard Webb fundamentally disagrees

Looking out for number one

All mammals take 21 seconds to urinate, and wombats defecate in cubes. Engineer Patricia Yang guides Chelsea Whyte through the fascinating ins and outs of our bodily fluids

FOR Patricia Yang, bodies are a series of tubes fine-tuned to pump the gory and the gross: blood, urine and faeces. A mechanical engineer at the Georgia Institute of Technology, she studies the fluid dynamics of what goes round inside living bodies, and what comes out of them. She has won an Ig Nobel prize, which celebrates unusual science that makes people laugh, and it is well deserved.

Yang does the dirty work of handling faeces-filled wombat intestines, gathering pig's blood from slaughterhouses and designing makeshift elephant urethras – all for the sake of science. And she can't get enough of it.

When people ask what you do, what do you tell them?

I'm an engineer. I study blood, I study pee and I study poop. When I tell people that, they have a hard time linking engineering with biology, but I don't see a distinction between the two. Animals use engineering to survive. Body fluids work for us, carrying nutrition or waste or oxygen. These fluids have a purpose, and I want to know how they work.

How did you start studying bodily fluids?

I've liked animals since I was really young. When I started my PhD, my adviser was potty training his kid and had been doing a lot of waiting around for his son to pee. He had to do the



SUZIESZTERHAS/FLIPA



ROB WALLS/ALAMY STOCK PHOTO

Wombats have a tendency to go cubical in the cubicle

same thing with his dog. He wanted to know what urination was like at the extremes – for the smallest animals and the largest. He asked me how long it would take for an elephant to pee. I said, "I'll study anything as long as I can spend time at the zoo."

How did you go about finding out how long elephants take to urinate?

Surprisingly, there are a lot of animal urination videos on YouTube. When zoo visitors see animals peeing, they film it and post it online. The videos told us we had about 10 to 20 seconds to catch an elephant peeing on camera. ➤



PIETER ESPEEL/GETTY

First, we practised. We got an acrylic pipe – about a metre long and thicker than your arm. I had a collaborator pour a bucket of water through it, and we practised focusing and changing the camera settings to get the right lighting. Then we went to the zoo.

Did you have to wait around for the elephants to need the toilet?

We started a collaboration with Atlanta's zoo. The elephant keeper told us the two elephants pee every day at 7 am. So we took our high-speed camera, got there early and waited.

What did you find when the urine eventually started flowing?

Before this study, our team thought the urethra was just a pipe that connects an animal's bladder to the outside world, but we found that it also accelerates the flow. It sounds trivial, but when we started, if you asked professors of engineering how long it would take for an elephant to empty its enormous bladder, they would say probably half an hour. But we built a model to calculate the rate for all animals weighing from 3 to 5000 kilograms, and it is 21 seconds. Tinier animals may break the rule by peeing in droplets rather than streams, but on the large end, there's no limit to the size at which 21 seconds applies. Maybe it extends all the way up to dinosaurs.

How did you move from studying the mechanics of urination to the hydrodynamics of faeces?

A lot of the animals we filmed pooped at the same time they peed. So we had a lot of data on both. We found that whether it was an elephant or a panda or a warthog, all the animals that poop in cylindrical form take 12 seconds to defecate – including humans! We also found out how important the mucus layers are. Your colon is like a chute that is lined with mucus to help faeces slide out. Bigger animals have more mucus, so can shift more volume more quickly.

Is there more scatological research to be done?

Yes. There are so many types of faeces: watery cow pies, rodent and rabbit pellets, cylindrical faeces from humans and other mammals, and then we have wombat faeces. They poop in cubes.

We know that the water content dictates whether faeces will be a pie, pellets or a cylinder. Pellet-pooing animals have large intestines that are about four times as long as those of similar-sized animals that make cylindrical poop, so they absorb more

An African pipit sits on elephant dung

water and leave drier faeces behind. But how does a wombat poop in cubes?

We contacted the Memphis Zoo and they packed up some wombat faeces and mailed it to us. It was very cubic, but it had dried out by the time it got to us. So we started a collaboration with a biologist in Australia, where wombats are a common form of road kill. We asked if he could send us some wombat guts. He said, "How many do you need? I have 10 in my freezer."

What did you do when you got your hands on some wombat guts?

To see if the gut expanded in a special way that formed the cubes, we cut a section and inserted a long, thin balloon – the kind used to make balloon animals. By inflating the balloon, we found two areas of the intestine cross-section that expanded less than the others, which would likely be the source of half of the corners.

We're still working on it, but I think the other corners may come from the intestine's alignment within the body. Maybe these corners are formed by pressure from other organs arranged around it.

What's next for your body fluid research?

I'm working in a blood lab now. Every two days, we go to a sausage factory slaughterhouse to pick up pig's blood. Sometimes we have a spill in the lab and it looks like a murder scene.

Blood is interesting because how fast it flows can change what happens inside the body. If your blood vessels narrow, the blood will flow faster, and cause clotting. Some drugs can stop those clots, but at the expense of more bleeding elsewhere in the body, so I'm trying to understand the mechanics to stop the clotting or the extra bleeding.

I'm also continuing my poop research. When I give talks about faeces, the audience raises a lot of interesting questions.

Someone told me that female turkeys poop in spirals but males don't. When I heard that, I thought it sounded crazy. But I want to understand how it works. ■

"I'm working in a blood lab now. Sometimes we have a spill and it looks like a murder scene"

Chelsea Whyte hopes you enjoy your Christmas turkey

Science, fix me a drink

Can the latest research help create incredible cocktails?
New Scientist selflessly upended several highballs to find out



The classic negroni was a useful benchmark

WHITE chocolate with caviar, salmon with liquorice, bananas with parsley. Heston Blumenthal started the craze: according to the principles of “molecular flavour pairing” espoused by the UK chef in the early 2000s, these duos were natural platefellows, sharing flavour compounds that suggested explosive taste sensations when combined.

Blumenthal later characterised this as “bumptious enthusiasm”, a folly of youth that overlooked the true complexities of how the thousands of molecules in any foodstuff make flavour. “I now know that a molecule database is neither a shortcut to successful flavour combining nor a fail-safe way of doing it,” he wrote in *The Times* in 2010. “If I’d known then what I know now, I would probably never have tried this method of flavour pairing.”

Well, we do know now what he didn’t know then. As gastronomic science has continued its remorseless advance, we have gained ever more insights into how chemistry, physiology and perception combine to create sensations of true deliciousness. *New Scientist* has always championed evidence-based living, so it was time to put some of these insights to the test.

As good foot soldiers of the festive season, we decided to test them not on food, but on booze. On an unseasonably warm afternoon in early October, a troop of five *New Scientist* staff – four thirsty editors and a photographer to record the results – were to be found just off a suburban backstreet in north London with one question on our lips: could science create the ultimate cocktail sensation? ➤

THE CLASSIC COCKTAIL: THE NEGRONI

Take equal measures of gin, Campari and vermouth and mix. Pour over ice and garnish with an orange slice

A key component of any scientific test is the control. Classic cocktail combinations exist for a reason – widespread acclaim – so to calibrate our scoring system for the experimental concoctions to follow, we needed first to sample an acknowledged hit.

Our host for the afternoon, Carlos Chuliá, development chef at Kitchen Theory, a gastrophysics research outfit and restaurant in Barnet, London, recommended the negroni. This gin-based combination apparently originated in 1919 in a bar in Florence, Italy. "It's a classic, and good for cleansing the palate," says Chuliá. Usefully for our critical faculties, it also packs quite a punch.

VERDICTS: "Floral on the nose, bitter on the palate." "An acquired taste." "You have to like bitter."

AVERAGE SCORE OUT OF FIVE: 🍷🍷🍷

OPPOSITES ATTRACT: LEMON, PEPPER AND CUCUMBER COLLINS

Fill cocktail shaker with ice, add 10ml Sichuan pepper syrup, 25ml gin, 50ml cucumber juice and 10ml lemon juice. Shake and serve.

For the Sichuan pepper syrup: bring 100ml water, 100g of sugar and 10g of Sichuan pepper to the boil and simmer at medium heat for 5 min. Cool and strain.

Even one drink down, the science behind cocktail recipes was starting to feel less important. Fortunately, one of our number had read the research beforehand and brought it along on a piece of paper.

Controlled experiments weren't kind to the first iterations of molecular flavour pairing: blind taste tests suggested paired combinations fared no better than unpaired combinations.



KIRSTIN KIDD

In 2011, physicist Sebastian Ahnert and his colleagues, then at Northeastern University in Boston, gave things a more scientific footing. They used principles of network theory to analyse 56,000 recipes from North America, Europe and Asia, checking to see if the ingredients shared flavour compounds.

They found that recipes from western Europe and North America did, but those from eastern Europe and Asia generally did not. In these places, the tendency seemed to be to combine ingredients with the fewest flavour molecules in common.

Our "opposites attract" cocktail, whipped up by Chuliá, took this discovery as an inspiration. For a variation on the classic gin cocktail, the Tom Collins, he chose three ingredients from very different parts of Ahnert's flavour network: lemon, cucumber and Sichuan pepper.

And the result was indeed surprisingly pleasant – and nothing like the titanic clash of flavours you might expect.

VERDICTS: Thumbs up. "Rushing rivers and watercress." "Like sitting on a veranda surrounded by English flowers." "Amazingly mild." "Where's the alcohol in it?"

AVERAGE SCORE: 🍷🍷🍷🍷



THE PAIRED COCKTAIL: BEETROOT, COFFEE AND ANISEED MULE

Take 20ml each of vodka and beetroot juice, 10ml each of sambuca and hibiscus kombucha and 5ml cinnamon syrup, pour over ice and mix well. Strain into a glass, then cover with yogurt foam and sprinkle with coffee grounds.

For the yogurt foam: mix 70ml Greek yogurt, 50ml water, 50ml sugar syrup, 20ml egg white and 10ml lemon juice in a blender, pour into a whipped-cream dispenser and charge with two nitrous oxide cartridges.

A deficiency of network-based flavour pairing theory is that it fails to take into account concentrations of flavour molecules or the thresholds at which they must be present for us to perceive them, says Jozef Youssef, the chef-patron of Kitchen Theory. Ahnert says he is now working to incorporate detection thresholds into a new flavour network, though this work is not finished.

While we wait for that breakthrough, we wondered whether there might be a way to get the most out of current flavour pairing know-how, which says that similar-tasting ingredients and very different-tasting ingredients can





Chef Carlos Chuliá creates his lemon, pepper and cucumber Collins (pictured far left) and a fresh take on the paloma

neglected this crucial point.

Our final cocktail rectified that, abandoning the idea of finding thrilling new flavour combinations and focusing on the ordering of tastes. "We're following a traditional recipe but freshening it," says Chuliá, bullishly. "Because this is gonna be better."

We chose a paloma, a classic long mix of grapefruit soda and tequila traditionally served with salt on the rim of the glass. The salt blocks bitter taste receptors on the tongue, making the grapefruit taste sweeter. In much the same way, sodium lauryl sulphate, a detergent commonly found in toothpaste, blocks sweet receptors, making orange juice taste bitter after brushing.

With a traditional paloma, however, the salt is all gone after a few sips. Chuliá instead mixed up a salt foam and laid it on top of the drink to avoid this problem. "You're in this continuous loop of salt and grapefruit," he says. But is that a place where anyone would want to be? It was noses down to find out.



VERDICTS: Mixed. "Fresh and consistent." "Luscious." "Like sipping out of the washing-up bowl, but I don't mind it." "I just don't like it."

AVERAGE SCORE: ★★★★★

OVERALL VERDICT

It was an afternoon of surprises: the complexity of the flavours developed in the beetroot, coffee and aniseed mule, for example, or the floral harmony of the pairing of opposing elements in the lemon, pepper and cucumber Collins.

It may be a measure of the amount of alcohol imbibed that our assessments became more fractious and less consistent as the session wore on. But the fact that all our newfangled cocktail concoctions scored higher than a classic negroni suggests that the appliance of science has much to offer the casual cocktail mixer. They are to be enjoyed in moderation, of course, but do try this at home. ■

New Scientist is feeling better now

both complement each other. Could we explode a mega-volcano of cocktail taste? A recipe originally developed for a sambuca manufacturer by Foodpairing, a consultancy in Belgium headed by Peter Coucquyt, gave us an opening.

To build his concoction, Coucquyt, a former chef of a Michelin-starred restaurant, started with the anise-flavoured liqueur sambuca and looked for ingredients with similar flavour molecules that would pair well with it. That led him to beetroot, whose earthy flavour comes from the molecule geosmin. And to coffee, whose similarly earthy notes come from compounds called pyrazines.

But Coucquyt went one further. "When I create, I use food pairing to find the aromatic matches," he says. "But then you have your experience as a chef too." That told him that the earthy notes would be beautifully balanced by the mild sour notes of yogurt. Did it work?

VERDICTS: Hit the spot. "It socks you with aniseed, but then reveals a whole fulfilling underworld of beetroot." "Awesome complexity." "Psychedelic, or is that just the alcohol talking?"

AVERAGE SCORE: ★★★★★

ORDER IS EVERYTHING: THE PALOMA, REFRESHED

Pour 250ml grapefruit juice, 100ml tequila, 12ml vanilla syrup and the juice of half a lemon into a soda siphon. Add some ice. Charge with one carbon dioxide cartridge, shake and let go. Repeat with a second cartridge. Strain into a glass, then add salt foam on top.

For the vanilla syrup: bring 100ml water, 60g sugar and 8g vanilla extract to the boil. Let it cool, then refrigerate.

For the salt foam: blend 500ml water, 5g salt and 4.3g lecithin with a handheld electric blender, incorporating air into the mix until it foams on top.

If you have ever drunk orange juice just after brushing your teeth, you will have experienced a fundamental truth of flavour perception: order matters. In 2017, Youssef and his long-time collaborator Charles Spence at the University of Oxford, who studies how we perceive food, pointed out that attempts to find new, interesting combinations of flavours have rather

"It tastes like sipping out of the washing-up bowl, but I don't mind it"



CULTURE

Unauthorized Bread

The spirit of goodwill to all? There must be an app for that somewhere, says **Cory Doctorow**, in our exclusive extract from his new novella

THE way Salima found out that Boulangism had gone bankrupt: her toaster wouldn't accept her bread. She held the slice in front of it and waited for the screen to show her a thumbs-up emoji, but instead, it showed her the head-scratching face and made a soft *brtt*. She waved the bread again. *Brtt*.

"Come on." *Brtt*.

She turned the toaster off and on. Then she unplugged it, counted to ten and plugged it in. Then she menued through the screens until she found "Reset to factory default", waited three minutes, and punched her wifi password in again. *Brtt*.

Long before she got to that point, she'd grown certain that it was a lost cause. But these were the steps that you took when the electronics stopped working, so you could call the 800 number and say, "I've turned it off and on, I've unplugged it, I've reset it to factory defaults and..."

There was a touchscreen option on the toaster to call support, but that wasn't working, so she used the fridge to look up the number and call it. It rang 17 times and disconnected. She heaved a sigh. *Another one bites the dust*.

The toaster wasn't the first appliance to go (that honour went to the dishwasher, which stopped being able to validate third-party dishes the week before when Disher went under), but it was the last straw. She could wash dishes in the sink but how the hell was she supposed to make toast – over a candle?

Just to be sure she asked the

fridge for headlines about Boulangism and there it was: its cloud had burst in the night. She prodded a headline and learned that Boulangism had been a ghost ship for at least six months because that's how long security researchers had been contacting the company to tell it that all its user data – passwords, logins, ordering and billing details – had been hanging out there on the public internet with no password or encryption. There were *ransom notes* in the database, inserted by hackers demanding payouts in exchange for keeping the dirty

"The dishwasher stopped validating third-party dishes the week before when Disher went under"

secret of Boulangism's shitty data-handling. No one had even seen them.

Boulangism's share price had declined by 98 per cent over the past year. There might not even be a Boulangism any more. When Salima had pictured Boulangism, she'd imagined the French bakery that was on the toaster's idle-screen, dusted with flour, woodblock tables with serried ranks of crusty loaves. She'd pictured a rickety staircase leading up from the bakery, to a suite of cramped offices overlooking a cobbled road. She'd pictured gas lamps.

The article had a Streetview shot of Boulangism's headquarters, a four-story office block in Pune, near Mumbai, walled in with an unattended

guard-booth at the entrance.

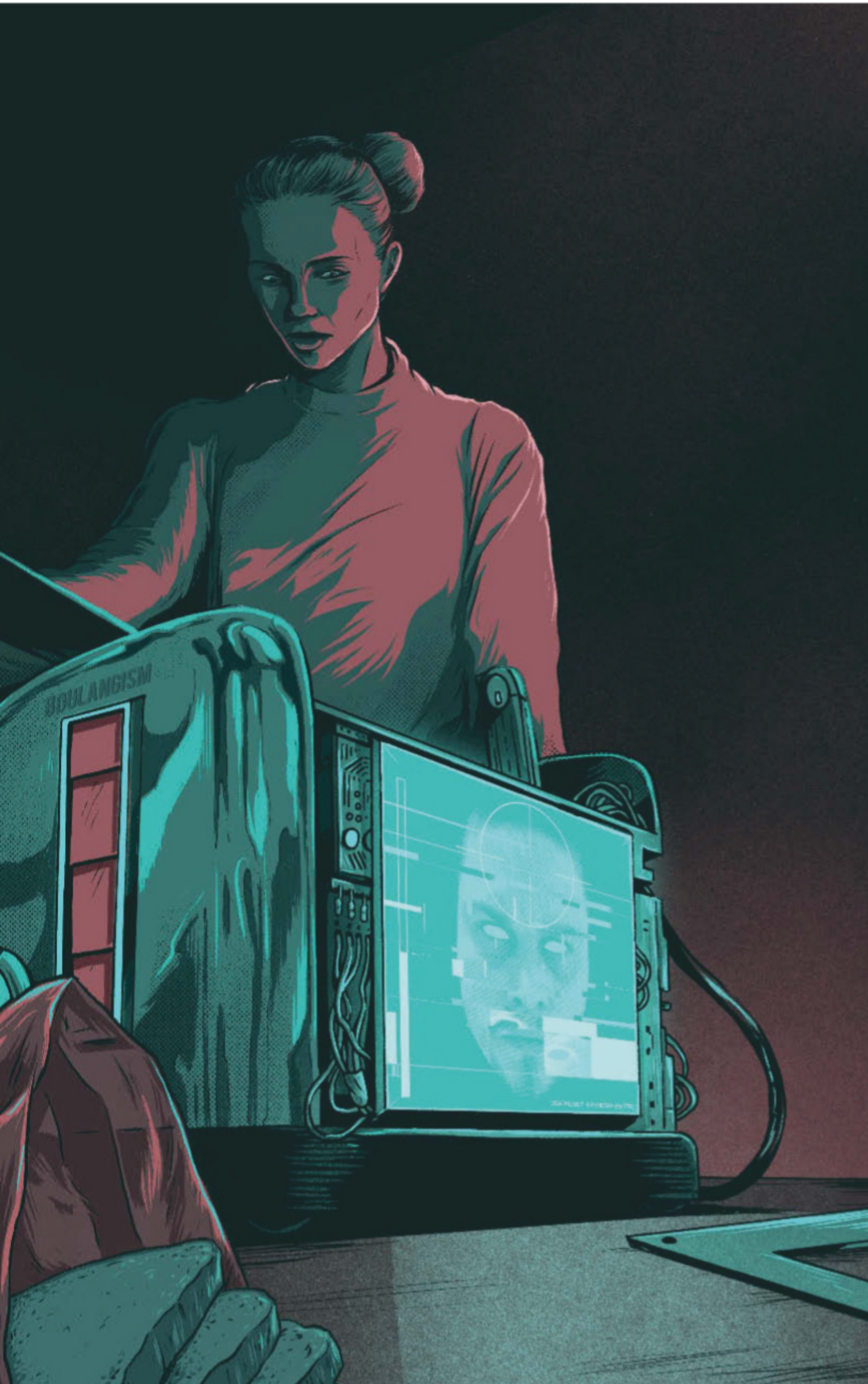
The Boulangism cloud had burst and that meant that there was no one answering Salima's toaster when it asked if the bread she was about to toast had come from an authorized Boulangism baker, which it had. In the absence of a reply, the paranoid little gadget would assume that Salima was in that class of fraudsters who bought a discounted Boulangism toaster and then tried to renege on her end of the bargain by inserting unauthorized bread, with consequences ranging from kitchen fires to suboptimal toast (Boulangism was able to adjust its toasting routine in realtime to adjust for relative kitchen humidity and the age of the bread, and of course it would refuse to toast bread that had become unsalvagably stale), to say nothing of the loss of profits for the company and its shareholders. Without those profits, there'd be no surplus capital to divert to R&D, creating the continuous improvement that meant that hardly a day went by without Salima and millions of other Boulangism stakeholders waking up with exciting new firmware for their beloved toasters.

And what of the Boulangism baker-partners? They'd done the right thing, signing up for a Boulangism licence, subjecting their process to inspections and quality assurance that meant that their bread had exactly the right composition to toast *perfectly* in Boulangism's precision-engineered appliances, with crumb and porosity in ideal

JOE WILSON



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balance to absorb butter and other spreads. These valued partners deserved to have their commitment to excellence honoured, not cast aside by bargain-hunting cheaters who'd recklessly toast any old bread.

Salima knew these arguments, even before her stupid toaster played her the video explaining them, which it did after three unsuccessful bread-authorisation attempts, playing without a pause or mute button as a combination of punishment and re-education campaign.

She tried to search her fridge for "boulangism hacks" and

"Their bread had exactly the right composition to toast perfectly, with crumb and porosity in ideal balance"

"boulangism unlock codes" but appliances stuck together. KitchenAid's network filters gobbled up her queries and spat back snarky "No results" screens even though Salima knew perfectly well that there was a whole underground economy devoted to unauthorized bread.

She had to leave for work in half an hour and she hadn't even showered yet but goddamnit, first the dishwasher and now the toaster. She found her laptop, a relic of her school days, underneath a pile of papers about her college loans. Its battery was long dead and she had to unplug her toothbrush to free up a charger cable, but after she had booted it and let it run its dozens of software updates, she was able to run the darknet browser she still had kicking around and do some judicious googling.

Her Boulangism didn't go easily. After downloading the new firmware from the darknet, she had to remove the case (slicing through three separate tamper-evident seals and a large warning sticker that threatened electrocution and prosecution, perhaps simultaneously, for anyone foolish enough to



CULTURE

ignore it) and locate a specific component and then short out two of its pins with a pair of tweezers while booting it. This dropped the toaster into a test-mode that the developers had de-activated, but not removed. The instant the test-screen came up, she had to jam in her USB stick (removing the toaster's hood had revealed a set of USB ports, a monitor port, and even a little Ethernet jack, all stock on the commodity single-board PC that controlled it) at exactly the right instant, then use the on-screen keyboard to tap in the login and password, which were "admin" and "admin" (of course).

It took her three tries to get the timing right, but on the third try, the spare login screen was replaced with the pirate firmware's cheesy text-art animation of a 3D skull, which she smiled at – and then she burst into

"She didn't know anyone who actually baked bread. That was like gnawing your own furniture out of logs"

laughter as a piece of text-art toast floated into the frame and was merrily chomped to crumbs by the text-art skull, the crumbs cascading to the bottom of the screen and forming shifting little piles. Someone had put a lot of effort into the physics simulation for that ridiculous animation. It made Salima feel good, like she was entrusting her toaster to serious craftspeople and not just randos who liked to pit their wits against faceless programmers from big, stupid companies.

The crumbs piled up as the skull chomped and the progress indicator counted up from 12 per cent to 26 per cent then to 34 per cent (where it stuck for a full ten minutes, until she was ready to risk really bricking the damned thing by unplugging it, but then...) 58 per cent, and so on, to an agonising wait at 99 per cent, and then all the crumbs rushed up from the bottom of the screen and

went back out through the skull's mouth, turning *back* into toast, each piece forming up in ranks that quickly blotted out the skull, and the words ALL DONE burned themselves into the toast's surface, glistening with butter that ran down in rivulets. She was just grabbing for her phone to get a picture of this awesome pirate load-screen when the toaster blinked and rebooted itself.

A few seconds later, she held a slice of bread to the toaster's sensor and watched as its light turned green and its door yawned open. Halfway through munching the toast, she held her hand up to the toaster, palm out, as though it, too, were a slice of bread. The toaster's light turned green and the door opened. She was tempted to try and toast a fork or a paper towel or a slice of apple, just to see if the toaster would do it, but of course it would.

This was a new kind of toaster, a toaster that took orders. A toaster that would give her enough rope to hang herself, let her toast a lithium battery or a can of hairspray, or anything else she wanted to toast: unauthorized bread. Even homemade bread. The idea made her feel a little queasy and a little tremorous. Homemade bread was something she'd read about in books, seen in old dramas, but she didn't know anyone who actually baked bread. That was like gnawing your own furniture out of whole logs or something.

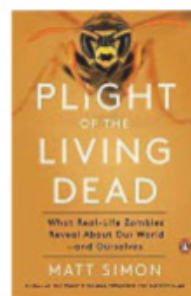
The ingredients turned out to be incredibly simple and while her first loaf came out looking like a poop emoji, it tasted *amazing*, still warm from the little toaster, and if anything, the slice (OK, the lump) she saved and toasted the next morning was even better, especially with butter on it. ■

Cory Doctorow is a British-Canadian blogger, journalist and science fiction writer who serves as the co-editor of the website Boing-Boing. *Unauthorized Bread* is first in a four-part short story series, *Radicalized*, published by Head of Zeus on 19 March 2019

Real zombies live!

From insects to humans, nothing is safe from mind-stealing parasites, discovers **Adrian Barnett**

Plight of the Living Dead: What real-life zombies reveal about our world – and ourselves by Matt Simon, Penguin



IF YOU feel that commercialism has taken over your body this festive season, driving you to make costly and irrational

decisions, then spare a thought for the cockroach, one of the humble heroes of Matt Simon's foray into the world of real-life zombies.

These insects won't succumb to overenthusiastic purchases ("Do have another date – we've got 17 boxes") or dread the error that makes junior's chin tremble ("it's an XJ11ii, but I wanted an XJ13iv!"). No, zombie cockroaches are driven by a more sinister force, that results in their untimely death, carrying the progeny of a parasitic wasp. The wasp injects the roach's brain with a series of chemicals so finely tuned they subvert the very behavioural

sequences roachkind uses for survival, tweaking them for the benefit of the wasp larvae, deep inside the hapless host.

This kind of mind control is also practised by species from fungi that infiltrate ants to toxoplasmosis parasites that make mice think cat pee smells great. To get those spores, eggs or larvae out and about, some will even try to stack the deck by altering the behaviour of a host to ensure the next generation ends up in a favourable spot.

Simon captures the subtlety and complexity of this, managing to be witty, well-informed and awestruck at the same time. His journey from forest to lab details the tricks and false treats parasites hand out to dupe hosts and bend them to their will, with a gripping finale about human infestation and free will undermined. A cracking Christmas read. ■

Adrian Barnett is a rainforest ecologist at Brazil's National Institute of Amazonian Research in Manaus

Whether it is cockroaches or ants, parasites infest and steal minds



A moon for all nations

Every country's lunar programme spins a different story about its purposes, finds **Philip Ball**

ON 7 December, China launched a mission to carry a lander and rover to the surface of the moon. On the eve of the half-centenary of Apollo 11's moon landing and Neil Armstrong's famous fluffed line about a small step for a man, the Chinese moonshot, called Chang'e 4, may be an indication of where mastery of space – not to mention Earth – is shifting.

The Apollo missions asserted US dominance at the height of the cold war, which is why Armstrong and Buzz Aldrin planted the US flag in the Sea of Tranquility. But going to the moon was not just a reassertion of supremacy after the humiliation of the Soviet Union launching the first satellite, Sputnik 1, and cosmonaut Yuri Gagarin completing the first Earth orbit. It also upheld the manifest destiny of Americans to venture into the unknown in search of opportunity.

Neither was the Soviet space programme just a flexing of military muscle. "There was an expectation after the second world war that space was just around the corner," says Doug Millard, deputy keeper of technologies and engineering at London's Science Museum. "There was a feeling of positivism and progress, that technology would deliver and solve everything."

Since the beginning of the Soviet state, space travel has been associated with utopianism, exemplified by 19th-century visionary Nikolai Fedorov and his colleague Konstantin Tsiolkovsky. The latter's drawings of spacecraft, cosmonauts and orbital space stations in the 1930s look like preparatory sketches both for Apollo and Stanley Kubrick's 1968 epic *2001: A Space*



NI SHUBIN XINHUA/EYEVINE

Odyssey. For the US, going to the moon was all about rugged, pragmatic individualism; for the Soviets, it was a parable for their communal social philosophy.

This enactment of national myth is apparent in the Chinese moon programme. Chang'e is the name of a goddess who flew

"For the US, going to the moon was all about rugged, pragmatic individualism"

to the moon after she drank an elixir of immortality to stop her husband's enemy from stealing it: a story of heroic and dutiful self-sacrifice that underlies China's Moon Festival in the autumn. In the era of Chairman Mao

The beauty of the moon has long sparked human imagination

Zedong, such stories were ridiculed as remnants of decadent imperialism, but more recently the government has revived legends and historical figures such as Confucius to mobilise nationalist sentiment.

Witness the way the mariner Zheng He of the early Ming dynasty has been portrayed as a benign envoy of Chinese culture, now linked to the "soft power" that an expansionist China is extending to its neighbours.

"Under Xi Jinping, there's a longer-term plan of exerting Chinese power on a global stage," says Millard – and the aspirations in space are a part of that.

The Indian space agency ISRO launched its first lunar probe, Chandrayaan-1, in 2008, and a Mars orbiter in 2013. "I'd say that space is very symbolic of national pride there," says Mark McCaughrean at the European Space Agency. Space also acts as an eye-catching advertisement for technical prowess. "ISRO has a commercial arm, and their Mars mission was meant to show that Indian expertise could deliver," says Millard.

What, then, of Europe? The European dream – what remains of it – has always been about cooperation, explicitly renouncing the nationalism that wrought such destruction in the 20th century. "The way our team developed and managed the outreach campaign for the Rosetta mission [to comet 67P/Churyumov-Gerasimenko in 2014] and the way it was perceived worldwide was perhaps representative of a more European feel: no flags being waved, allowing everyone to be involved," says McCaughrean.

Can that kind of egalitarianism deliver enough inspiration, before dissolving into bureaucracy? Right now, that is the question testing European institutions as a whole.

Nations do not lightly undertake moon missions, yet what is there to gain from them? Sure, there is interest in understanding the moon and its origins – but plans for human space flight to our satellite have never really been about science. Space missions generally, and moonshots in particular, enact and reflect the stories nations tell themselves. ■

Philip Ball is a science writer based in London

CULTURE

Unpicking the mythologies around the dark web

Take a walk on the web's wilder side with **Douglas Heaven**

"DO NOT click the link! Do not click the link!" The floppy-haired young man screams at his laptop, but we know his friends are going to die anyway. It is why we watch horror films.

A group of twenty-somethings are hanging out via video chat. One of them is using a laptop that someone left behind in a cafe. He shows his friends a hidden folder that connects him to a strange part of the internet.

"Dude, this is dark web," says one of them.

"What's dark web?" another asks.

"Drugs, illegal IDs, even assassinations for hire."

"Whoa!"

"Yeah, the dark web is mostly about the bad guys."

Released in UK cinemas in August, the film *Unfriended: Dark Web* (directed by Stephen Susco) is now out on DVD and streaming services. It is OK if you like scares on rails. But the new twist is the choice of baddie.

The laptop turns out to contain dozens of grainy videos that show people chained up in basements or stuffed inside barrels. The friends realise that these snuff videos are being made and traded online by a ring of sadistic killers.

The fun begins when a member of this ring pops up in the friends' video chat to ask for his laptop back. But the real monster here is the dark web itself. *Unfriended* taps into the popular idea of a shadowy, unmapped part of the internet where nasty things lurk.

"It's a seductive, terrifying trope, the idea that some



UNIVERSAL PICTURES

monstrous collection of horrifying data lurks beneath the reach of the average web user," writes Robert Gehl in *Weaving the Dark Web* (MIT Press), a terrific analysis of the web's wildest, oddest frontier.

An internet ethnographer at the University of Utah, Gehl is good at unpicking the mythology. He draws on three years of observing the dark web, noting what people do and interviewing those doing it. Along the way, he contributed to wikis, ran a blog, hosted a homepage and even helped edit a dark web literary magazine.

"The term Dark Web very likely evokes some decidedly illegitimate associations: drug markets, unregulated guns for

sale, child exploitation images, stolen credit cards for sale, or phishing attacks," he writes. He reminds us of Silk Road, the billion-dollar marketplace selling everything from psychedelic mushrooms to heroin. Slickly run by Ross Ulbricht, aka Dread Pirate Roberts, Silk Road became a kind of underworld Amazon.

We also hear reports generally that terrorist cells are setting up encrypted and untraceable communication channels. And that the dark web is where the spoils from massive personal data thefts – such as the names and credit card details of people who used the adultery site Ashley Madison – end up for sale.

While we tend to remember the

Nasty things lurk on the dark web in the film *Unfriended*

sensational stories, Gehl writes that for "each nefarious use of the Dark Web, we can find beneficial uses". Newspapers such as *The New York Times* and *The Guardian* have dark websites so that whistle-blowers can upload information without revealing their identities. In fact, *The New York Times* mirrors its website on the dark web so people living under oppressive censorship can visit without being tracked. It is a safe place for dissidents worldwide.

This was one of the main reasons the dark web came into being. Gehl gives us the full history of the technical infrastructure

For more books and arts coverage, visit newscientist.com/culture

needed. In 1999, Ian Clarke, a computer scientist at the University of Edinburgh, UK, drew attention to two flaws in the design of the 10-year-old web. By using a public addressing system and routing software that could be traced, the web was too easy to monitor and censor.

As Gehl puts it: "If our reading habits and publications are always tied to us, Clarke reasons, powerful entities such as governments or corporations could use that information to control us. Moreover, if the web relies on centralized infrastructures, such as DNS [which translates names into internet addresses], blocking access to particular sites – say,

physics, chemistry and engineering". Others simply want to escape the Sauron's eye of Facebook and Google.

True, most dark web guides, such as Jamie Bartlett's excellent *The Dark Net* (Windmill Books), use "dark" in a moral sense. And the US documentary series *Dark Net* (Showtime) has episodes on cyber-kidnapping, digital warfare, porn addiction and online cults.

But, for Gehl, a moral definition doesn't cut it. "Some Dark Web sites are downright boring, providing cat facts, highly specialized computer networking technology discussions... or a means to play chess anonymously," he writes. Plenty of the dark web is about as dark as the rest of the internet.

And it isn't very hidden. Anyone who installs a free browser upgrade to Chrome or Firefox can go there. Not only can you browse it like the rest of the web, but it has search engines. Many dark web sites want to be found. Before it was shut down, AlphaBay, a market similar to Silk Road, hired a PR firm to publicise it on normal web forums.

It even gets hacked. Last month, attackers deleted more than 6500 websites from a popular server called Daniel's Hosting, which many used to host dark web sites.

Gehl prefers a technical definition: "The Dark Web functions much like the regular web – with the key exception that one needs special routing software to access it."

Whether the dark web is the best response to the weaknesses of the regular web is up for grabs. As with other anonymising tech such as bitcoin, being able to hide your identity has obvious benefits for those up to no good. What is plain, though, is that the dark web is not such a bad place. Gehl is one of the few commentators bringing light to the darkness. ■

Douglas Heaven is a technology writer, based in London

"In theory, nobody knows who runs the dark web's websites or who visits them"

those critical of ruling parties and leaders – is trivial."

Clarke was right. Surveillance capitalism (as we now know it) tracks everything we do on the web – and our attention is manipulated by someone for profit. In many parts of the world, governments block websites that work against their interests.

Clarke went on to develop Freenet as a decentralised, anonymous alternative to the web. Others soon followed with Tor and I2P (the Invisible Internet Project). These three networks together make up the dark web.

Rather than immoral or hidden, we should think of the "dark" in dark web as representing a communications blackout. The single factor that distinguishes it from the rest of the web is that it runs on software that obfuscates the routes web traffic takes, so users cannot be traced. In theory, nobody knows who runs its websites or who visits them.

People use dark web forums to share topics that are illicit for some, says Gehl, including "political theory, gender studies,

DON'T MISS



Watch

Based on a true story, Robert Zemeckis's *Welcome to Marwen* (pictured above) tells the tale of a damaged man, played by Steve Carrell, who sets about literally rebuilding the past. It opens in UK cinemas on 1 January 2019.

Listen

There have been more than 320 instalments of the Australian podcast Science on Top. According to the last one we caught, there is a tornado of dark matter hurtling towards us – though it being dark matter, this doesn't really, er, matter.

Watch

This year's Royal Institution Christmas Lectures examine human uniqueness. They start on BBC4 at 8 pm GMT on 26 December. Biological anthropologist Alice Roberts and geneticist Aoife McLysaght give it their all.

Read

Armchair philosophers and problem-solvers will enjoy engineer Paul Nahin's *How to Fall Slower Than Gravity – and other everyday (and not so everyday) uses of mathematics and physical reasoning* (Princeton University Press).

Watch

Richard Adams's classic, *Watership Down*, traumatised a generation while introducing environmental issues. A new adaptation starts at 7 pm GMT on 22 December on BBC1. International viewers can catch it on Netflix.

Listen

Tune in to BBC Radio 5 Live on 24 December (time to be confirmed) to celebrate *Christmas on the Far Side of the Moon*, with a recording of transmissions from the Apollo 8 crew in lunar orbit, 50 years ago.

Play

The early release version of Curve Digital and Hugel Studios' *When Ski Lifts Go Wrong* has had us falling off our chairs with laughter (and cancelling our ski trips) for some weeks now. The new year will see it fully released on Steam and Nintendo DS. Mind how you go.

Listen

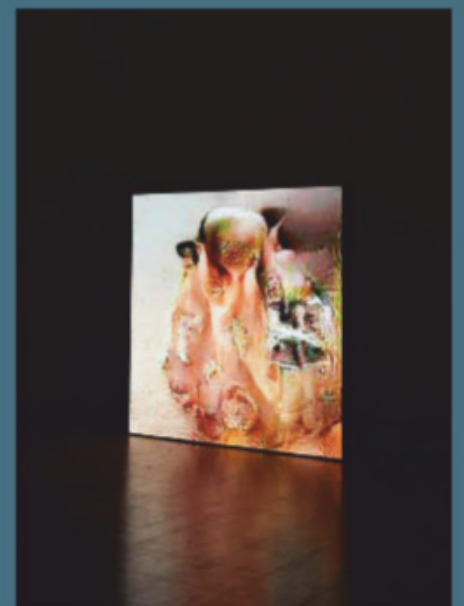
On BBC World Service at 9 am GMT on 27 December, Rajan Datar presents *The Forum's* globe-spanning history of fermentation. Finally, 200 years after we began to understand the processes involved, we are waking up to its health benefits.

Visit

Pierre Huyghe's UUmwelt uses artificial intelligence to create shimmering, spellbinding digital canvases (pictured below). It is on at London's Serpentine Gallery until 10 February 2019.

Last chance

Closing on 6 January is artist John Walters's CAPSID, a multimedia gallery show that conveys the wonders, beauties and horrors of the viral realm. Catch it (as it were) at Home in Manchester, UK.



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The 2019 Louisa Gross Horwitz Prize for Biology or Biochemistry

NOMINATIONS

All materials must be written in the English language and submitted electronically at:

<http://www.cumc.columbia.edu/research/horwitz-prize>

Deadline date: January 22, 2019

Renominations are by invitation only.
Self-nominations are not permitted.

The Louisa Gross Horwitz Prize was established under the will of the late S. Gross Horwitz through a bequest to Columbia University and is named to honor the donor's mother. Louisa Gross Horwitz was the daughter of Dr. Samuel David Gross (1805-1889), a prominent surgeon of Philadelphia and author of the outstanding *Systems of Surgery* who served as President of the American Medical Association.

Each year since its inception in 1967, the Louisa Gross Horwitz Prize has been awarded by Columbia University for outstanding basic research in the fields of biology or biochemistry. The purpose of this award is to honor a scientific investigator or group of investigators whose contributions to knowledge in either of these fields are deemed worthy of special recognition.

The Prize consists of an honorarium and a citation which are awarded at a special presentation event. Unless otherwise recommended by the Prize Committee, the Prize is awarded annually. Bert W. O'Malley, MD, Baylor College of Medicine; Ronald M. Evans, PhD, Salk Institute for Biological Studies and Howard Hughes Medical Institute; and Pierre Chambon, MD, Institute for Advanced Study of the University of Strasbourg, Institut de Génétique et de Biologie Moléculaire et Cellulaire are the 2018 awardees.

Qualifications for the award

The Prize Committee recognizes no geographical limitations. The Prize may be awarded to an individual or a group. When the Prize is awarded to a group, the honorarium will be divided among the recipients, but each member will receive a citation. Preference will be given to work done in the recent past.

Nominations should include:

- 1) A summary of the research on which this nomination is based (no more than 500 words).
- 2) A summary of the significance of this research in the fields of biology or biochemistry (no more than 500 words).
- 3) A brief biographical sketch of the nominee, including positions held and awards received by the nominee.
- 4) A key publication list of up to ten of the nominee's most significant publications relating to the research noted under item 1.
- 5) A copy of the nominee's curriculum vitae.



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Representative publications:

Arthritis Rheumatol. 67:2061-70, 2015
Arthritis Res Ther. 18:161, 2016
Rheumatic and Musculoskeletal Dis. 2 (2), 2016
Proc. Natl. Acad. Sci. (USA) 15:4755, 2018

Qualifications:

- PhD and/or MD in molecular biology, cell biology, immunology, genetics, or related field
- Working knowledge of immunology, arthritis models, signal transduction, transcriptomics and protein chemistry
- Ability to work collaboratively with individuals from different backgrounds
- Excellent verbal and written communication skills

Contact:

Please forward a cover letter, an updated CV, and the names and contact information of 3 references to:

Joseph Holoshitz, MD, Professor of Internal Medicine,
 University of Michigan School of Medicine, 5520 MSRB1
 1150 W. Medical Center Drive, Ann Arbor, MI , 48109-5680

Email: jholo@med.umich.edu



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<https://careers.utrgv.edu/postings/19706>

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Assistant Professor in Materials Chemistry, # FRGV0856

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EDITOR'S PICK

My experience of coping with Parkinson's



From Mike Aris,
London, UK

Clare Wilson reports that in Parkinson's disease many of the core symptoms are caused by the loss of automatic movements, that many previously automatic tasks require conscious effort, and that this could be the basis for early diagnosis (1 December, p 12).

As a person with Parkinson's, the loss of automatic movement has long been obvious to me. Acceptance of the need to replace or reinforce this with conscious effort has led me to very simple yet effective ways of dealing with many of the symptoms.

For example, when faced with a series of tasks – a situation that can lead to grinding to a halt or “freezing” – it helps me enormously to sub-vocalise a series of detailed instructions or a running commentary as I go along. I can largely overcome the problem of my handwriting becoming vanishingly small by naming the letters as I write them, rather than relying upon an unconscious subroutine to execute the whole word. I think of this as “linguistic scaffolding” for actions. It is a bit tedious to begin with but it is well worth persevering.

Making carbon taxes popular with credits

From Matthew Benton,
Bristol, UK

Carbon taxes are probably a vital tool for weaning humanity off fossil fuels and onto clean renewables (17 November, p 7 and p 22). Unfortunately people rarely vote for more taxes, and unpopular taxes will probably increase climate change denial.

A solution might be the carbon dividend, where revenue from a carbon tax is not kept by the government, but paid out equally to citizens to offset energy price rises. Middle and low income earners should gain most, since the wealthy consume more energy. Importantly, green energy would look more economically attractive. This proposal uses a free-market mechanism to fix a problem largely caused by free-

market economics. But with emissions rising, maybe this small economic risk is worth taking before any high-risk fixes such as geoengineering.

In the US, conservative groups such as the Climate Leadership Council and Americans for Carbon Dividends, hope to push this idea in the 2020 elections.

Maybe we should exploit rainforests - carefully

From Iain Climie,
Whitchurch, Hampshire, UK
Paying Brazil to conserve its rainforest, as Craig Sams suggests, has obvious appeal (Letters, 1 December). But it could easily go the way of Ecuador's failed Yasuni initiative. That country found oil under its Yasuni rainforest reserve but offered to leave it alone. In return, it asked the wider world for partial compensation for lost



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"We will pay fuel taxes when corporations pay all their taxes and stop hiding in tax havens"

Lea Leeloo takes issue with the idea that gilets jaunes protesters in France primarily oppose climate taxes (15 December, p 26)

income and jobs. Ecuador said this didn't materialise, and oil extraction is now under way.

There is an effective alternative. In his book *The Diversity of Life*, biologist E. O. Wilson pointed out the big benefits that could be obtained by exploiting such areas carefully without clearing them, and even costed up the ideas. His figures suggested the long-term benefits far exceed those from short-term damaging use.

Flattening rainforests for beef and soya is bad enough; logging, mineral extraction, dam building and cultivating coca, biofuels and other cash crops are even worse.

Extinction Rebellion: the planet's best, last hope

From Derek Langley,
Cambridge, UK

I was heartened by your report on the launch of Extinction Rebellion

(10 November, p 4). In the face of government intransigence, I believe this climate protest group is the planet's best, last hope, and I would encourage all your readers to get involved. For my part, I am proud to say that I have been arrested twice for standing up for the future of my grandchildren and all life on Earth.

Please don't forget rural transport

From Andrew Vickers,
Quernmore, Lancashire, UK
Alice Klein quotes Mark Nieuwenhuijsen of the Barcelona Institute of Global Health in Spain reminding us that we have forgotten that cities are meant to be for people, not cars (27 October, p 22). Please don't forget rural areas. Pollution may be less of a problem here, but we don't have pavements or street lighting.

Transport is necessary but not at the higher speeds often allowed on narrower rural roads. Walking or cycling with my children to their primary school was always a tense affair.

I have two radical suggestions to complement a ban on cars in cities. Firstly, a new national speed limit of 70 kilometres per hour (45 miles per hour) on all roads where lower limits don't already apply, except motorways and designated dual carriageways (divided highways). Secondly, speed limiters on all vehicles, set at 120 kph (75 mph). Perhaps then car makers would focus on the safety of those outside the vehicle, not technology for faster driving.

Of course the motor industry will object, claiming restriction of personal freedom, but our grandchildren will probably look at our behaviour in cars in 2018 with horror.

Turn coal into gas to reduce its impact

From John Watson,
Darlington, County Durham, UK
The hosting of the UN climate change conference by the coal mining town of Katowice, Poland, and its sponsorship by coal firm JSW highlighted the economic dependence on coal in such countries (Leader, 8 December). I do appreciate the importance of ultimately stopping the use of fossil fuels, but suggest that an interim step for coal could be to gasify it rather than burn it.

The gas produced by this process can be stored and used as a smokeless means of generating electricity and, unlike coal, can be fired up or switched off rapidly to meet changes in demand. The cleaner exhaust gases produced should be amenable to the use of carbon capture technology. ➤

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More ways to deal with the home heating issue

From Michael Hutchinson, Pamber Heath, Hampshire, UK
Michael Le Page makes a number of important points about the role of household heating in carbon emissions (17 November, p 22). But surely the answer in the UK, at least in the next few decades, is to develop gas-powered heat pumps for domestic use. These are more efficient than gas boilers.

As you point out, 85 per cent of homes in the UK are already connected to the gas network, so infrastructure is already there. We just need to adapt the technology, which already exists for industrial applications, for domestic use.

From Derek Knight, Holmer Green, Buckinghamshire, UK

Do solar panels not have their part to play in changing domestic heating to combat climate change? They may not be the most efficient energy source in northern countries such as the UK, but at least they completely substitute carbon dioxide-producing fuel. I have had 16

panels installed, and find that the saving in electricity bills is nowhere near the cost (plus loan interest) that I paid for them. If the government wants to help cut climate-changing emissions, it needs to help with this cost.

Slow thinking concludes that it may not exist

From Ed Subitzky, New York, US
Madeleine Finlay discusses the presumption that there are two types of decision-making (17 November, p 38). My type 1 system (fast and intuitive) believes that type 1 and type 2 systems do exist. After reading the article, my type 2 system (slow and analytical) isn't so sure.

The pernicious effects of a vitamin being stored

From Frank Hollis, Small Dole, West Sussex, UK
Writing about diet supplements, Linda Geddes says that water-soluble vitamins cannot be stored (1 December, p 30). Vitamin B₁₂ is water soluble, but it is stored, mainly in the liver. The amount

stored can be enough to satisfy the body's needs for years.

This is one reason why a vitamin B₁₂ deficiency can be hard to diagnose. Even if somebody cannot absorb any B₁₂ – for example in pernicious anaemia – levels in the body can decrease very slowly. Many people put symptoms such as fatigue, memory lapses and clumsiness down to increasing age. Often it is only when severe signs of harm arise, such as peripheral neuropathy, in which nerves are damaged, that someone visits a doctor. It is then often too late to completely fix the damage.

The ups and downs of a green Christmas

From Chris Good, Maidenhead, Berkshire, UK
Alice Klein and Chelsea Whyte say that even the fanciest fake festive tree is going to be sorry-looking in 20 years, the point at which they have an ecological advantage over real trees (1 December, p 22). We bought our fake tree well over 40 years ago and it is still very presentable, despite being lent to

an amateur dramatic society for a performance of *Pickwick*. We have recovered its cost several times over by avoiding buying a tree each year. Everyone who wants a tree for Christmas should buy an artificial one and stop razing land best left to grow proper trees and store carbon dioxide.

From Ralph Hancock, London, UK
I'd be wary of wishing people a "Green Christmas". An old proverb has it that "a green Christmas means a full graveyard". Mild weather at Christmas will, in other words, be followed by a spell of killing cold.

Kenyan seagrass loss is a drop in the ocean

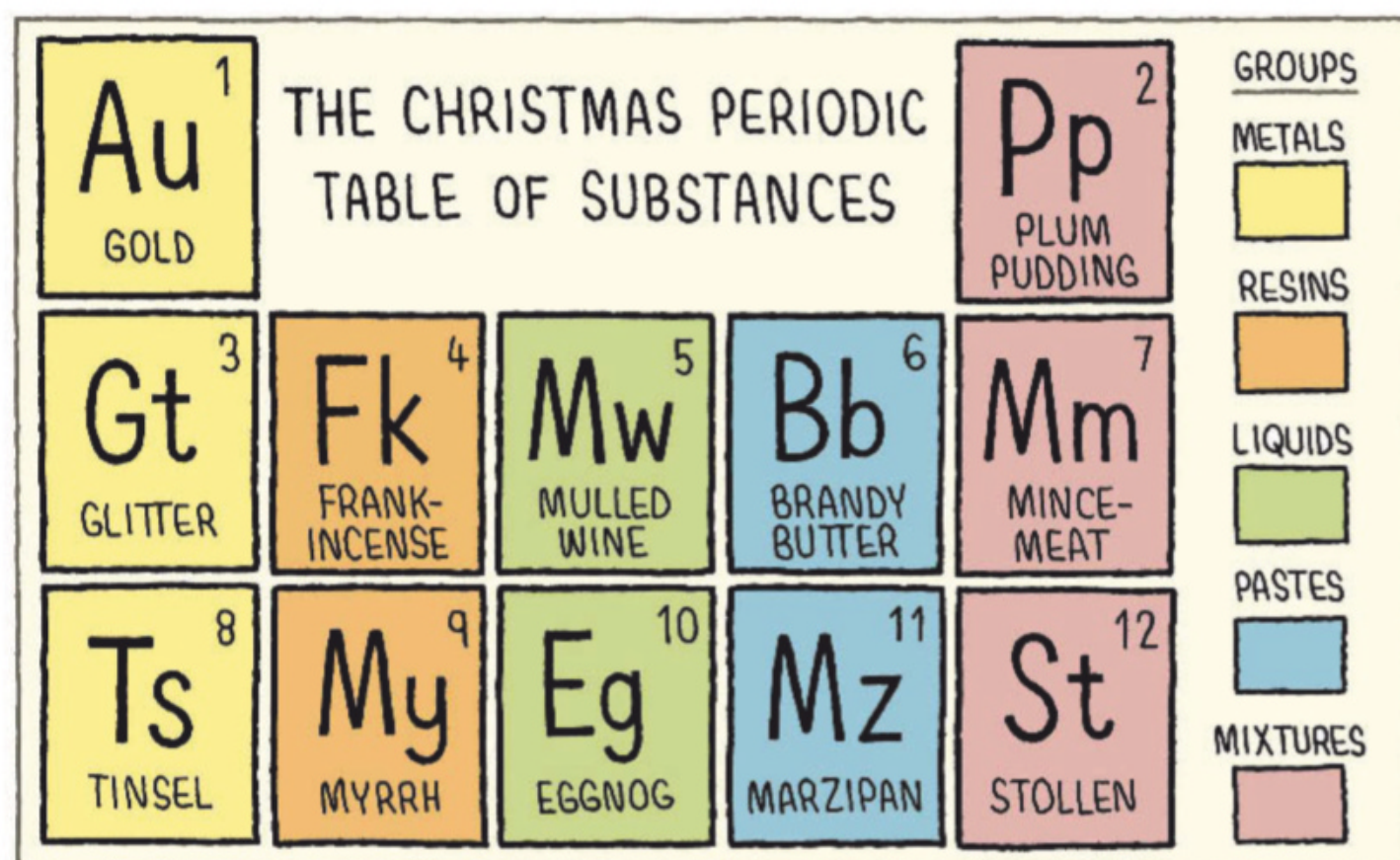
From Eric Kvaalen, Les Essarts-le-Roi, France
You tell us that seagrass loss off Kenya has added 7 million tonnes of atmospheric carbon dioxide over the past 30 years (1 December, p 15). That's about 230,000 tonnes per year. We are putting about 30 billion tonnes of CO₂ into the air each year, or about 130,000 times as much.

We could talk about bees' milk as well as spiders'

From Barry Hill, Ledbury, Herefordshire, UK
At the end of an interesting article on spiders' maternal behaviour, you state that milk secretion is exclusive to mammals (8 December, p 20). Another non-mammal that certainly has glands that produce brood food and feeds this to its young is the honey bee. You can buy "honey bee milk" as "royal jelly".

Letters should be sent to:
Letters to the Editor, New Scientist,
25 Bedford Street, London, WC2E 9ES
Email: letters@newscientist.com

Include your full postal address and telephone number, and a reference (issue, page number, title) to articles. We reserve the right to edit letters. New Scientist Ltd reserves the right to use any submissions sent to the letters column of *New Scientist* magazine, in any other format.



TOM GAULD for NEW SCIENTIST

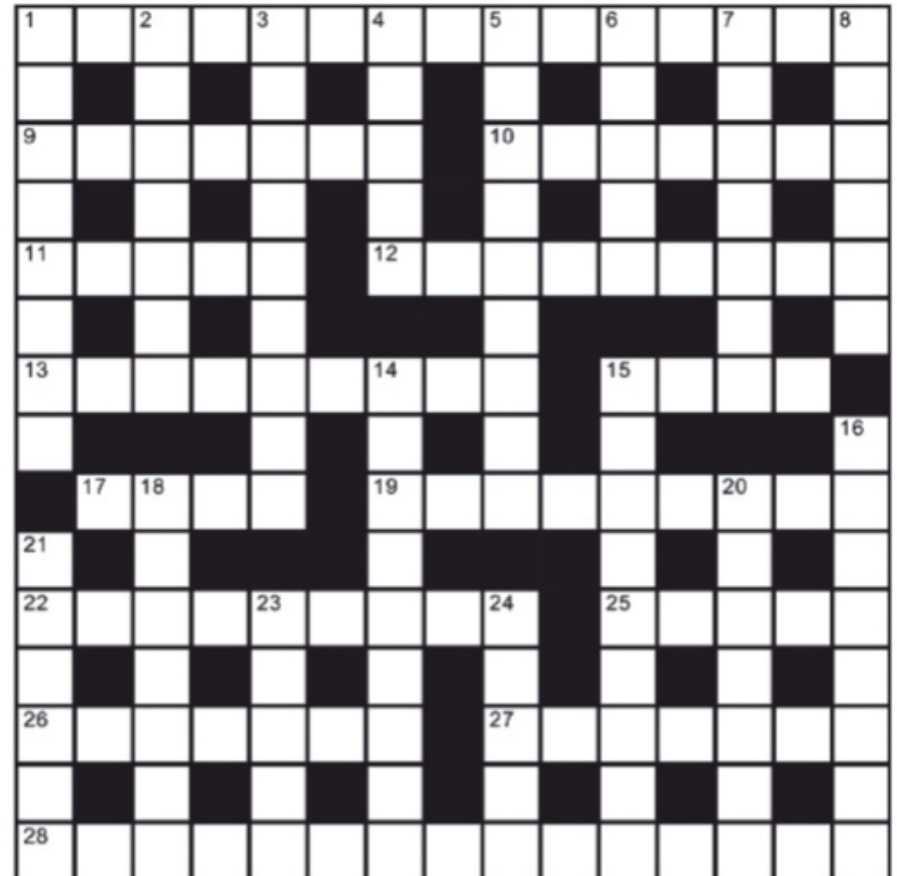
FESTIVE CROSSWORD

Set by Sparticle and Wingding

Tell us what you think at crossword@newscientist.com

Holidays, science and exercise for your brain – who could ask for more?

Here are two sets of crossword clues with different answers for the same grid. Good luck!



Cryptic clues

ACROSS

- 1 Festive delivery arranged in teenager's shop? (15)
- 9 Pine, say, for Nice model (7)
- 10 Agreed to be tugged or barged? (2,5)
- 11 Big investor in mid-range LEDs (5)
- 12 Instruments with an indicator of volume in the worst places (9)
- 13 Real subjects of the theory of relativity? (9)
- 15 Phenomenon at the heart of riverbed dynamism? (4)
- 17 Unsolved exercise in Newton's last letters (4)
- 19 In group illuminated a number: the right way to behave (9)
- 22 Encourages fashionable ghost to meet primary schoolers (9)
- 25 Acid test a Geneva complex introduced for clock (5)
- 26 Trinket designed by machine with gain of ten decibels (7)
- 27 Frosted flakes: gruel with a little protein added (7)
- 28 Sly Mr Fox stymied nervous snowflakes' grand design? (7,8)

DOWN

- 1 Canine collective gets older presents (8)
- 2 Scientist synthesises nitrogen without electrical current (7)
- 3 Pretentious half-Inuit engineer (9)
- 4 Pole position or nth in line (5)
- 5 Cartridges dropped in lotion manufacturing plant (9)
- 6 Tycoon reverses natural scent embargo (5)
- 7 Put up bats returning light (7)
- 8 Typical of setters of bones, a dismal bunch of characters (6)
- 14 As a mother is on chicks, or so *The Selfish Gene* would say? (9)
- 15 Place most prepared to produce paranormal matter (9)
- 16 Plant can say hello (3,5)
- 18 Drop a letter here to reprogram bots in the grip of virus (7)
- 20 Astronomical phenomenon *New Scientist* covered in top US review (7)
- 21 Halo I'm beginning to behold in the rising sun (6)
- 23 House starts getting liquid between one and two degrees? (5)
- 24 Weightless conditions in space give your heads a slushy feeling (5)

Quick clues

ACROSS

- 1 The third woman to win a Nobel prize in physics, *New Scientist* reported in October (5,10)
- 9 Site of ice spikes on Jupiter's moon Europa, as NS reported in October (7)
- 10 A new shape discovered in our cells, NS reported in July (7)
- 11 Less restricted (5)
- 12 Remove dead skin cells (9)
- 13 Russian pie (9)
- 15 Methods (4)
- 17 We might soon be able to reproduce without these, NS reported in April (4)
- 19 Previously unknown astronomical objects, NS reported in October (9)
- 22 Double entendres (9)
- 25 Nigerian currency (5)
- 26 Tumour of connective tissue (7)
- 27 Variety of rice with high levels of the aroma compound 2-acetyl-1-pyrroline (7)
- 28 Branch of artificial intelligence used in 2018 to generate video games, short stories and horror masks (7,8)

DOWN

- 1 Machine-doctored video proliferating in 2018 (8)
- 2 Newly arrived (7)
- 3 We've lost track of more than 900 of these, NS reported in May (9)
- 4 A baby conceived with the help of mitochondrial replacement therapy is said to have this many genetic parents (5)
- 5 By the fact itself (4,5)
- 6 Projecting knob (5)
- 7 Unexpected result (7)
- 8 Bumper car (6)
- 14 Instant (9)
- 15 Marconi, Feynman and Schrödinger have been called this on account of their relationships (9)
- 16 Measuring the chemical composition of a sample (8)
- 18 The UK National Health Service plans to buy more drugs of this type, NS reported in January (7)
- 20 Japanese art that has inspired robot design, as NS reported in June (7)
- 21 Style of Chinese cuisine (3,3)
- 23 Bacterium that killed US consumers of romaine lettuce, NS reported in May (1,4)
- 24 Type of antelope (5)

Answers to Quick crossword No25

ACROSS: 8 KEYPAD, 9 MYCELIUM, 10 STARLING, 11 INCHES, 12 NINETEEN, 13 TARMAC, 14 DONNA STRICKLAND, 18 STABLE, 20 NEPHRITE, 23 VIOLET, 24 MICRODOT, 25 SEQUENCE, 26 IBIDEM.
DOWN: 1 NEUTRINO, 2 SPURGE, 3 C DRIVE, 4 IMAGINARY NUMBER, 5 ECLIPTIC, 6 GLYCEROL, 7 EUREKA, 15 NOBELIUM, 16 SMELTING, 17 NITROGEN, 19 TRIJET, 21 PECTIN, 22 RHOTIC

Answers and the next quick crossword from Richard Smyth will be in the 12 January 2019 issue

FEEDBACK

For more feedback, visit newscientist.com/feedback



PAUL MCDEVITT

TURKEYS may vote for Christmas, but what about canaries? Festive-minded Robert Campbell recently purchased a couple of roasting dishes from Lidl. The attached notes warn him not to "overheat your cooking utensils, so as to avoid smoke which can be dangerous for small animals (e.g. birds) with especially sensitive respiratory systems. We recommend not keeping birds in the kitchen!".

Robert says he was unaware that kitchens were off limits for birds, while Feedback wonders why it is up to the vendors of kitchenware to raise awareness of this danger and not, say, the vendors of small birds.

This is of particular concern to us, as our own kitchenette is packed with a seasonal gift haul: a small flock of swans and geese, four calling birds, three french hens, a pair of turtle doves and a partridge. (We also received a pear tree, which is sitting in the garage.)

While our incumbent guests will certainly keep us mindful not to overdo the parsnips, we suppose

any accidental fatalities will only put extra meat on the table. Turducken? So 2017! Make ours a six-layer meat matryoshka: swagoo callhendovtridge.

SPEAKING of seasonal food, it's not just European nationalists who hold a deep-seated loathing for Brussels. We are talking sprouts, of course. Brassicaphobic readers will be thrilled to hear that a new study has revealed one weird trick to dampen the green gremlin's bitter taste.

Volunteers reported that a sip of red wine considerably lowered the sprouts' intensity. Gravy and water had no effect. Researchers say the wine's astringency may somehow counter bitter tastes. All you need to know is that a fruity red is just the thing to wash down your Christmas dinner – whether sprout infested or not.

'TIS the season when millions of people who couldn't keep a cactus alive decide to bring a mature fir tree

into their home. Keeping this festive pot plant alive until the 12th day of Christmas can be a challenge, but technology is here to help.

Engineers at the Massachusetts Institute of Technology have created a cyborg plant that can drive itself about. Electrodes inserted in the plant detect its reactions to light, heat and more, and cause the wheels to relocate the plant to a comfier spot.

Of course, the idea of waking up to find a tinselled triffid looming over your bed, its cold, sap-filled heart intent on revenge, should be enough to have you reaching for the hatchet. Best play it safe and buy an artificial tree this year.

A DOG is for life, but adorable animals are for any day of the week. The question is: why do most of us get the urge to squeeze cute creatures?

Psychologists have dubbed the phenomenon "cute aggression". In a new study, 54 people looked at pictures of animals and babies while EEG caps recorded their brain activity. The results suggest these aggressive urges happen when people can't handle how cute something is.

Katherine Stavropoulos at the University of California, Riverside, says, "Our study seems to underscore the idea that cute aggression is the brain's way of 'bringing us back down' by mediating our feelings of being overwhelmed."

IN A previous edition, Feedback reported signage that declared a running tap wastes "250 penguins or £22 a day" (24 November). "This exchange rate makes one penguin worth 8.8p," says Ian Binnie. "Where can I buy a penguin for 8.8p, and are these the fairy or king kind?"

Feedback urges Ian to waddle down to the biscuit aisle of his local supermarket, where we are sure he can p-p-pick up a penguin for around that price.

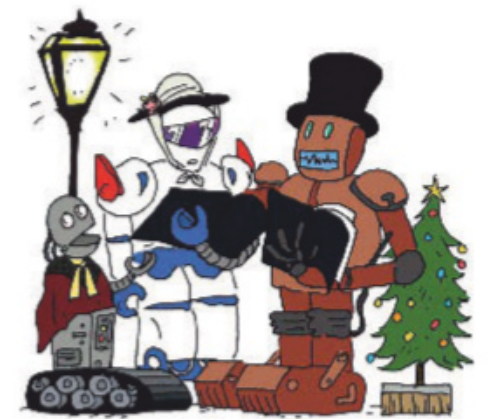
AND finally, it wouldn't be the holidays without a little carolling. In what is bound to become a

time-honoured tradition, researchers at Made by AI have raised a machine-learning intelligence on a steady diet of Christmas carols, and asked it to produce some new ones.

Visit christmas.madeby.ai to listen to spirited renditions of future classics such as *Cinnamon Holybells*, *Merry Jinglelog* and the charming *Cocoa Jollyfluff*.

Not to be outdone, the panoptical AI behind Google's search algorithms is also having a go. Search for "partridge in a pear tree" and you will be treated to an information box containing what this machine intelligence believes to be the correct lyrics. The first few lines are spot on, but things quickly get weird:

"Better not shout, you better not cry / You better not in a pear tree / On the ninth, no! / On the eighth, come on!..."



Nine ladies dancing they were dancing for me / Eight maids a milking they were milking just for me / I had Christmas down in Africa... I had Christmas down in Africa (five golden rings) / Couldn't take the halls into the things we never had... Partridge in a big pear tree / Partridge in a big pear tree"

What more is there to say? Merry Christmas, happy Hanukkah, jolly Yule and season's greetings one and all.

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week's and past Feedbacks can be seen on our website.

A walking, talking android was lauded as the most advanced of its kind when it appeared at a recent Russian technology forum. Alas, Robot Boris was in fact an unnamed man in a £3000 costume

QUIZ OF THE YEAR

Hair's looking at you

What's the punk turtle's secret power? Test your knowledge of 2018's scientific trivia against **New Scientist's** resident quiz bot

2018 was the year AI seemed finally to be conquering all... or at least the headlines in *New Scientist*. A horde of stories revealed how AI is variously eavesdropping on Borneo's forests, deciding matters of life and death in driverless cars and gaining its own theory of mind.

So it may come as a relief that our seasonal quiz is set by, and firmly intended for, old-school human intelligence. Let your wetware loose on these questions, covering some of the comfortingly inconsequential stories that have appeared over the past year in the pages of your favourite **RUNTIME ERROR**



CHRIS VAN WYK/ZSL/PA

1. In January, what echo of classic science fiction came closer to science fact?

- a) planet-less moons wandering through interstellar space
- b) a dark, rectangular object in orbit around Jupiter
- c) a plan to launch a mission to the moon using a giant cannon

2. In February, which altruistic animals did we highlight?

- a) chiropodist bees that bite parasites off bee feet
- b) chiropractor elephants that sit on other elephants with backache
- c) nurse ants that lick the wounds of comrades

3. In June, palaeontologists were surprised to find that Stone Age inhabitants of Körtik Tepe in eastern Turkey had which modern-day leisure-related ailment?

- a) jogger's nipple
- b) surfer's ear
- c) zorber's forehead

4. Also in June, which mathematical marvel of the animal kingdom did we reveal?

- a) pigeons that do probability
- b) giraffes that do geometry
- c) camels that do calculus

5. What snag in terraforming Mars to allow large-scale colonies to be built emerged in August?

- a) it lacks a protective magnetic field
- b) there's not enough carbon dioxide in the atmosphere
- c) asteroids will be much cheaper to build on

6. Also in August, we revealed that the US navy is developing what non-lethal weapon to stop enemy boats?

- a) mucous slime, inspired by hagfish exudations
- b) silky nets, inspired by spiders' webs
- c) long sticks, inspired by stick insects

7. Physicists have been busy trying to prove definitively that quantum weirdness really does explain reality. To do this, what did they recruit, as we reported in November?

- a) an almost infinite number of monkeys
- b) 100,000 video game players
- c) galaxies on opposite sides of the universe

8. Debate has raged this year as to whether the ancient life form known as Dickinsonia really is one of the first animals. In September we reported it had a cholesterol problem, but what very un-animal-like characteristic came to our attention in November?

- a) it could feed off the effluvium of volcanic vents
- b) it could inflate its entire body like a balloon
- c) it lived for more than 5000 years

9. Paper and ink were passé even for the Incas, we noted in September. What was their preferred writing system based on?

- a) avenues of stone idols, each weighing up to 2 tonnes
- b) intricately knotted cords
- c) human teeth

10. The Mary River or "punk" turtle (Elusor macrurus), pictured above, has what striking ability, according to a report in April?

- a) it can nourish itself from its recherché coiffure
- b) it can open mussel shells with its flippers
- c) it can breathe through its genitals

10. c) The turtle, native to Queensland, Australia, does grow a garden on its head, but doesn't seem to use it for food

9. b) Cords known as "khipu" had long been known to encode numbers, but their role in writing is only just being explored

8. b) The round, flat, underwater blob may have expanded to increase the area of the seabed it could feed off

7. b) and **c)** In separate tests, quantum researchers used gamers and intergalactic light to generate random settings for their experiments

6. a) The super-expanding slime would halt small boats by clogging their propellers

5. b) The greenhouse gas would be needed to raise temperature and pressure, making it possible to live without space suits

4. a) Pigeons are the first non-primates to grapple with statistics... probably

3. b) Why the bony ear growths common in people who are regularly exposed to cold water should have turned up in a site so far from the sea remains a mystery

2. c) Matabele ants (*Megaponera* *andalis*) nurse wounds sustained by their comrades in regular skirmishes with termites

1. a) Astronomers' simulations suggest there could be as many as 100 former moons wandering through space for every star in the Milky Way

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Colour me scientific

In that holiday spirit of both looking back on the past year and looking forward to a new one, we offer you two fresh, creative ways of celebrating the best and greatest of scientific endeavour.

Follow the instructions on the pages overleaf to reveal an icon of achievement against all odds that we remembered in 2018. If that tickles you pink, turn over again to create an image of an inspiring human undertaking we will be celebrating in 2019.

Images by **Thomas Pavitte** thomasmakesstuff.com



Available for download at:
newscientist.com/colour-me-scientific

HOW TO COLOUR A QUERKLE

It doesn't matter what you use to colour in the overlapping circles in a querkle. Just make sure you have five distinguishable colours, and that you shade areas numbered "1" the darkest, and those numbered "5" the lightest. Leave any areas without a number blank.

It's easiest to colour all of one number at a time, starting with the areas numbered "1". Perhaps experiment with using different grades of cross-hatching, paint and other media to achieve different effects. You might want to make some copies before you begin!



